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APPLICATIONS OF NANOTECHNOLOGY IN AGRICULTURAL SCIENCES

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ABSTRACT

Nanotechnology has great potential as it can enhance the quality of life through its applications in various fields like agriculture and the food system. In a world where the human population is growing rapidly, and agriculture industry is facing challenges such as stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies, climate change, shrinking arable land and water availability, post harvest losses and shortage of labour and thereby food security is a very important problem in near future. Now, increasing agricultural production efficiency and decreasing post harvest wastage using novel scientific researches such as nanotechnology in products could be counted as the best solution to this problem. Nanotechnology using of particular characteristics of nanoparticles can be a very useful technology in all science and industry branches. So now a lot of usage of nanotechnology in agricultural science has been founded. In relation with crop production, crop protection, storage, post harvest shelf life and marketing, nanotechnology can help us in some grounds like balanced crop nutrition, effective pest, disease and weed control, water management, product quality maintenance, product tracking and labeling, precision agriculture and agricultural waste management.

KEYWORDS: Nanotechnology, Agriculture, Applications

Nanotechnology was first introduced in 1960's by Dr. Richard Feynman. Since then scientists are working on it and have developed many technologies and applications of nano science. Nanotechnology, which deals with the matter at nanoscale (1-100 nm), is commonly referred to as a generic technology that offers better-built, safer, long-lasting, cost-effective and smart products that will find wide applications in household, communications, medicine, agriculture and food industry, amongst others. Nanotechnology-based products and its applications in agriculture include nano-fertilizers, nano-herbicides, nano-pesticides, recalcitrant contaminants from water, nano-scale carriers, nanosensors, detection of nutrient deficiencies, preservation, photocatalysis, nanobarcode, quantum dots etc. This fast growing technology is already having a significant commercial impact, which will certainly increase in the future. While nanotechnologies offer many opportunities for innovation, the use of nanomaterials in food and agriculture has also raised a number of safety, environmental, ethical, policy and regulatory issues.

Agricultural scientists are facing a wide spectrum of challenges such as stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies, climate change, shrinking arable land and water availability and shortage of labour besides exodus of people from farming. In spite of immense constraints faced, we need to attain a sustainable growth in agriculture at the rate of 4% to meet the food security challenges. To address these problems, there is a need to explore one of the frontier technologies such as 'Nanotechnology' to precisely detect and deliver the correct quantity of nutrients and pesticides that promote productivity while ensuring environmental safety and higher use efficiency. The nanotechnology can be exploited in the value chain of entire agriculture production system (Subramanian and Tarafdar, 2011). The nanotechnology aided applications have the potential to change agricultural production by allowing better management and conservation of inputs of crop production. A survey by Salamanca–Buentella *et al*. (2008) predicted several nanotechnology applications for agricultural production for developing countries within next 10 years. These included - (i) Nano forms zeolites for slow release and efficient dosage of water and fertilizers for plants; nanocapsules and herbicide delivery (ii) Nanosensors for soil quality and for plant health monitoring; nanosensors for pests detection (iii) Nanomagnets for removal of soil contaminants and (iv) Nanoparticles for new pesticides, insecticides, and insect repellents.

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The Indian Council of Agricultural Research (ICAR) has opened up an exclusive platform to target Nanotechnology Applications in Agriculture. The ICAR – Nanotechnology Platform encompasses major themes such as synthesis of nano-particles for agricultural use, quick diagnostic kits for early detection of pests and diseases, nano-pheromones for effective pest control, nano agri-inputs for enhanced use efficiencies, precision water management, stabilization of organic matter in soil, nano food systems and bio safety besides establishing the policy frame work. Green-synthesis and microbial synthesis of nanomaterials for their agricultural use may be very important as they are naturally encapsulated with mother protein, therefore, more stable and safer to biological system. At present in India research is mainly concentrated on nano particle synthesis, smart release of nutrients from nano-fertilizers, nano-induced polysaccharide powder for moisture retention/soil aggregation and C build up, regulated release of active ingredients from nano-encapsulated herbicides, nano-seed invigoration, and slow and steady release of pesticides, nano-film for extended shelf-life of perishables and nano-remediation of soil and aquatic pollutants. These are cutting-edge researchable areas which are expected to expand in the years to come. However, if the nano products and the processes for creating them are not managed judiciously, there could be serious health and environmental risks.

Application of Nanotechnology in Agricultural fields

Nanotechnology in Horticulture

Investigation confirms that application of nanotechnology in the horticulture was first in the fruit packaging and later in other areas such as tracking, tracing, storage and distribution. Currently, most nanotechnology applications in the horticultural supply chain are concentrated in packaging, mainly in the improvement of packaging materials for product security, quality and safety. The FAO put the global food losses and wastages during 2012 at 30– 40% and in developing countries more than 40% of the food losses occur at post-harvest and processing levels. In horticultural commodities, there are five stages at which post-harvest losses occur – production/harvest, post-harvest handling and storage, processing, distribution and consumption. Post-harvest losses represent a waste of resources used in production such as land, water, energy and inputs. Nanotechnology offers great scope not only to reduce the post harvest wastage but also aids in increasing the production efficiency. Nanotechnology has already associated with supply chain management, food quality, processing, preservation, vase life, handling, packaging and food safety. Nanocomposite polymers, antimicrobial packaging and nano packaging products are already in the market (Table 1). Using electro-spinning methodology, strong and naturally antimicrobial nanofibers were produced for developing the "green" food packaging (Neethirajan and Jayas, 2011). The novel edible films can be value-added by addition of functional ingredients as encapsulated nutraceuticals like vitamins, water-insoluble flavonoids, and other flavor/color enhancing phytochemicals, antioxidants like anthocyanins, carotenoids for avoiding discoloration of the cut surface and antimicrobial agents like bacteriocins (natural), biogenic nanoparticles of silver, titanium, or zinc (inorganic synthesized) to curb the growth of spoilage causing microbes (Rojas-Grau *et al*., 2009; Janjarasskul and Krochta, 2010; Oms-Oilu *et al*., 2010). Postharvest treatments with nano-silver significantly improve water relations and therefore prolong the vase life of several cut flowers. Nano silver and Nano copper ions in combination adapted from Miller and Senjen (2008) with biocides have been helpful in extending the vase life and quality of cut flowers like rose (Barbaz *et al.,* 2013), gerbera (Mousa *et al*., 2009), lilium (Maryam *et al.,* 2013) and tuberose (Asgari *et al*., 2013). Fruit ethylene efflux can be measured with great accuracy in a short period of time using nanotechnology in fruits like apple, avocado pear and kiwi which helps to open new avenues for the researchers which is otherwise could not be possible due to lack of real-time measurement equipments. Green tea with nano-packing, had better maintenance of vitamin C, chlorophyll, polyphenols and aminoacids than with normal packing (Hu and Fu, 2003).

Nanotechnology in seed science

Seed is most important input determining productivity of any crop. Conventionally, seeds are tested for germination and distributed to farmers for sowing. In spite of the fact that seed testing is done in well equipped laboratories, it is hardly reproduced in the field due to the inadequate moisture under rainfed conditions. In India, more than 60% of the net area sown is rainfed; hence, it is quite appropriate to develop technologies for rainfed agriculture. A group of research workers is currently working on metal oxide nano-particles and carbon nanotube to improve the germination of rainfed crops. Khodakovskaya *et al.* (2009) have reported the use of

Table 1. Commercialized nanotechnology products used for preservation and packaging of food particularly fruits/fruit-based products

Company/Supplier	Product name	Product description	Action/reference
Packaging			
Bayer	Durethan® KU 2-2601 Plastic wrapping	Nanoparticles of silica in a polymer-based nanocomposite	Nanoparticles of silica in the plastic prevent the penetration of oxygen and gas of the wrapping, extending the product's shelf-life
Song Sing nanotechnology	Nano ZnO plastic wrap	Nanoparticles of zinc oxide antibacterial, UV-protected food wrap	http://www.ssnano.net/ehtml/detail1.php?productid = 79
Nanobiosensors absorbers/indicators			
Kraft	Nano-sensor based 'electronic tongue'	Able to "taste" chemicals to the level of parts per trillion and then guide chemical release	Control the release of smell, taste and nutraceuticals into food products in response to the preferences of individual consumers (de Wolfe, 2009).
CSP Technologies	Multiple absorbers and indicators	Polymer capable of releasing ingredients into the food or beverage in response to external stimuli	Control over humidity, oxygen, bacteria, odor, and even the flavor of the food itself (LeGood and Clarke, 2006)
Life Lines Technology	Fresh Check	Polymer able to identify and monitor temperature changes w.r.t time	Time–temperature indicator for perishables (LeGood and Clarke, 2006)
Nanofruit drinks			
High Vive.com	Beverage fortified fruit juice	300 nm iron (Sun Active Fe)	http://www.highvive.com/sunactiveiron.htm
Jamba juice Hawaii	Beverage "Daily Vitamin Boost" fortified fruit juice	300 nm iron (Sun Active Fe) 22 essential vitamins and minerals	http://jambajuicehawaii.com/vita-boost.asp

Adapted from Miller and Senjen (2008)

carbon nanotube for improving the germination of tomato seeds through better permeation of moisture. Their data show that carbon nanotubes (CNTs) serve as new pores for water permeation by penetration of seed coat and act as a passage to channelize the water from the substrate into the seeds. These processes facilitate germination which can be exploited in rainfed agricultural system. Biosensors help in seed storage as seeds during storage emit several volatile aldehydes that determine the degree of ageing. These gases are harmful to even other seeds. Such volatile aldehydes can be detected and seeds showing signs of deterioration can be separated and invigorated prior to their use. Hence this technique can be employed in storage decision making.

Nano-fertilizers for balanced crop nutrition

In India, fertilizers, along with quality seed and irrigation, are mainly responsible for enhanced food grain production (55 mt) in 1960s to (254 mt) in 2011 coinciding with the spectacular increase in fertilizer consumptions from 0.5 mt to 23 mt, respectively. It has been conclusively demonstrated that fertilizer contributes to the tune of 35-40 per cent of the productivity of any crop. Considering its importance, the Government of India is heavily subsidising the cost of fertilizers particularly urea. This has resulted in imbalanced fertilization and occurrence in some areas, nitrate pollution of ground waters due to excessive nitrogen application. In the past few decades, use efficiencies of N, P and K fertilizers have remained constant as 30-35%, 18-20% and 35-40%, respectively, leaving a major portion of added fertilizers to accumulate in the soil or enter into aquatic system causing eutrophication. In order to address issues of low fertilizer use efficiency, imbalanced fertilization, multi-nutrient deficiencies and decline of soil organic matter, it is important to evolve a nano-based fertilizer formulation with multiple functions. Nano-fertilizer technology is very innovative but scantily reported in the literature. However, some of the reports and patents strongly suggest that there is a vast scope for the formulation of nano-fertilizers. Significant increase in yields has been observed due to foliar application of nano particles as fertilizer (Tarafdar, 2012; Tarafdar *et al*. 2012a). It was shown that 640 mg/ ha foliar application of nanophosphorus gave 80 kg/ ha P equivalent yield of cluster bean and pearl millet under arid environment. Similarly, nano-based ZnO application in peanut (Prasad *et al*. 2012) and maize (Venkatasubbaiah *et al.* 2016) has enhanced the yield. It was also reported for the first time that nano-based Ca had greater mobility in the phloem tissues, as bulk Ca is immobile (Deepa *et al.,* 2015) Currently, research is underway to develop nano-composites to supply all the required essential nutrients in suitable proportion through smart delivery system. Preliminary results suggest that balanced fertilization may be achieved through nanotechnology (Tarafdar *et al*., 2012b). Indeed the metabolic assimilation within the plant biomass of the metals, e.g., micronutrients, applied as Nano-formulations through soil-borne and foliar application or otherwise needs to be ascertained. Further, the Nano-composites being contemplated to supply all the nutrients in right proportions through the "Smart" delivery systems also needs to be examined closely. Currently, the nitrogen use efficiency is low due to the loss of 50-70% of the nitrogen supplied in conventional fertilizers. New nutrient delivery systems that exploit the porous nanoscale parts of plants could reduce nitrogen loss by increasing plant uptake. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients (Tarafdar *et al*., 2012c). In the next generation of nanofertilizers, the release of the nutrients can be triggered by an environmental condition or simply released at desired specific time.

Nano-herbicide for effective weed control

Weeds are menace in agriculture. Since two-third of Indian agriculture is rainfed farming where usage of herbicide is very limited, weeds have the potential to jeopardize the total harvest in the delicate agro-ecosystems. Herbicides available in the market are designed to control or kill the above ground part of the weed plants. None of the herbicides inhibits activity of viable belowground plant parts like rhizomes or tubers, which act as a source for new weeds in the ensuing season. Soils infested with weeds and weed seeds are likely to produce lower yields than soils where weeds are controlled. Improvements in the efficacy of herbicides through the use of nanotechnology could result in greater production of crops. The encapsulated nano-herbicides are relevant, keeping in view the need to design and produce a nano-herbicide that is protected under natural environment and acts only when there is a spell of rainfall, which truly mimics the rainfed system. Developing a target specific herbicide molecule encapsulated with nanoparticle is aimed for specific receptor in the roots of target weeds, which enter into roots system and translocated to parts that inhibit glycolysis of food reserve in the root system. This will make the specific weed plant to starve for food and gets killed (Chinnamuthu and Kokiladevi, 2007). Adjuvants for herbicide application are currently available that claim to include nanomaterials. One nanosurfactant based on soybean micelles has been reported to make glyphosate-resistant crops susceptible to glyphosate when it is applied with the 'nanotechnology-derived surfactant'.

Nano-pesticides

Persistence of pesticides in the initial stage of crop growth helps in bringing down the pest population below the economic threshold level and to have an effective control for a longer period. Hence, the use of active ingredients in the applied surface remains one of the most cost-effective and versatile means of controlling insect pests. In order to protect the active ingredient from the adverse environmental conditions and to promote persistence, a nanotechnology approach, namely "nano-encapsulation" can be used to improve the insecticidal value. Nano-encapsulation comprises nano-sized particles of the active ingredients being sealed by a thin-walled sac or shell (protective coating). Previously pheromones were combined with water-based gels (hydrogels), but this proved to be ineffective as the hydrogels either got evaporated due to exposure to heat and air or were washed away during monsoon. Recently, a pheromone-based nanogel to attract and trap the fruit flies in guava was developed. (Bhagat *et al.,* 2013 and Ipsita, 2014).

Nano-encapsulation of insecticides, fungicides or nematicides will help in producing a formulation which offers effective control of pests while preventing accumulation of residues in soil. In order to protect the active ingredient from degradation and to increase persistence, a nanotechnology approach of "controlled release of the active ingredient" may be used to improve effectiveness of the formulation that may greatly decrease amount of pesticide input and associated environmental hazards. Nano-pesticides will reduce the rate of application because the quantity of product actually being effective is at least 10-15 times smaller than that applied with classical formulations, hence a much smaller than the normal amount could be required to have much better and prolonged management. Several pesticide manufacturers are developing pesticides encapsulated in nanoparticles (OECD and Allianz, 2008). These pesticides may be time released or released upon the occurrence of an environmental trigger (for example, temperature, humidity and light). It is unclear whether these pesticide products will be commercially available in the short-term.

Plant diseases are major factors limiting crop yields. The problem with the disease management lies with the detection of the exact stage of prevention. Most of the time appropriate plant protection chemicals are applied to the crop as a precautionary measure leading to avoidable environmental hazards, or else applications are made after the appearance of the disease symptoms, thereby causing some amount of crop losses. Among the different diseases, the viral diseases are the most difficult to control, as one has to stop the spread of the disease by the vectors. But once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of the exact stage such as stage of viral DNA replication or the production of initial viral protein is the key to the success of control of viral diseases. Nano-based viral diagnostics, including multiplexed diagnostics kits development, have taken momentum in order to detect the exact strain of virus and the stage of application of some therapeutic to stop the disease. Detection and utilization of biomarkers, that accurately indicate disease stages, is also an emerging area of research in bio-Nanotechnology. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. Clay nanotubes (halloysite) have been developed as carriers of pesticides at low cost, for extended release and better contact with plants, and they will reduce the amount of pesticides by 70-80%, thereby reducing the cost of pesticide with minimum impact on water streams.

Nanotechnology in water management

Nanotechology, offers the potential of novel nanomaterials for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. Due to their unique activity towards recalcitrant contaminants many nanomaterials are under research and development for use for water purification. To maintain public health, pathogens in water need to be identified rapidly and reliably. Unfortunately, traditional laboratory tests are time consuming. Faster methods involving enzymes, immunological or genetic tests are under development. Water filtration may be improved with the use of nanofiber membranes and the use of nanobiocides, which appear promisingly effective. Biofilms contaminating potable water are mats of bacteria wrapped in natural polymers which are difficult to treat with antimicrobials or other chemicals. They can be cleaned up only mechanically, which cost substantial down-time and labour. Work is in progress to develop enzyme treatments that may be able to break down such biofilms.

Nano-scale carriers

Nanoscale carriers can be utilized for the efficient delivery of fertilizers, pesticides, herbicides, plant growth regulators, etc. The mechanisms involved in the efficient delivery, better storage and controlled release include: encapsulation and entrapment, polymers and dendrimers, surface ionic and weak bond attachments among others. These help to improve stability against degradation in the environment and ultimately reduce the amount to be applied, which reduces chemical runoff and alleviates environmental problems. These carriers can be designed in such a way that they can anchor plant roots to the surrounding soil constituents and organic matter. This can only be possible if we unravel the molecular and conformational mechanisms between the nanoscale delivery and targeted structures, and soil fractions. Such advances as and when they happen will help in slowing the uptake of active ingredients, thereby reducing the amount of inputs to be used and also the waste produced.

Biosensors to detect nutrients and contaminants

Protection of the soil health and the environment requires the rapid, sensitive detection of pollutants and pathogens with molecular precision. Soil fertility evaluation is being carried out for the past sixty years with the same set of protocols which may be obsolete for the current production systems and in the context of precision farming approaches. Accurate sensors are needed for in situ detection, as miniaturized portable devices, and as remote sensors, for the real-time monitoring of large areas in the field. These instruments are able to reduce the time required for lengthy microbial testing and immunoassays. Application of these instruments includes detection of contaminants in different bodies such as water supplies, raw food materials and food products. Enzymes can act as a sensing element as these are very specific in attachment to certain biomolecules. Electronic nose (E-nose) is used to identify different types of odours; it uses a pattern of response across an array of gas sensors. It can identify the odorant, estimate the concentration of the odorant and find characteristic properties of the odour in the same way as might be perceived by the human nose. It mainly consists of gas sensors which are composed of nanoparticles e.g. ZnO nanowires. Their resistance changes with the passage of a certain gas and generates a change in electrical signal that forms the fingerprint pattern for gas detection.

Smart delivery systems

Nanoscale devices are envisioned that would have the capability to detect and treat diseases, nutrient deficiencies or any other maladies in crops long before symptoms were visually exhibited. “Smart Delivery Systems” for agriculture can possess timely controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed, or multi-functional characteristics to avoid biological barriers to successful targeting. Smart delivery systems can monitor the effects of delivery of nutrients or bioactive molecules or any pesticide molecules. This is widely used in health sciences wherein nanoparticles are exploited to deliver required quantities of medicine to the place of need in human system. In the smart delivery system, a small sealed package carries the drug which opens up only when the desirable location or infection site of the human or animal system is reached. This would allow judicious use of antibiotics than otherwise would be possible.

Nanodevices for Identity Preservation (IP) and Tracking: One of the major constraints in Indian agriculture is the quality maintenance of agricultural produce. Proper monitoring of production system through nanotechnology will be appropriate to promote quality and make a clear distinction with organic products. Identity Preservation (IP) is a system that creates increased value by providing customers with information about practices and activities used to produce a particular crop or other agricultural products. Certifying inspectors can take advantage of IP as a better way of recording, verifying, and certifying agricultural practices.

Through IP, it is possible to provide stakeholders and consumers with access to information, records and supplier protocols. Quality assurance of agricultural products safety and security could be significantly improved through IP at the nano-scale. Nano-scale IP holds the possibility of continuous tracking and recording of the history which a particular agricultural product experiences. The nano-scale monitors may be linked to the recording and the tracking devices to improve identity preservation of food and agricultural products. The IP system is highly useful to discriminate organic versus conventional agricultural products.

Nanolignocellulosic materials: Recently, nanosized lignocellulosic materials have been obtained from crops and trees which had opened up a new market for innovative and value-added nano-sized materials and products, e.g. nano-sized cellulosic crystals have been used as lightweight reinforcement in polymeric matrix (Mathew *et al*., 2010). These can be applied in food and other packaging, construction, and transportation vehicle body structures. Cellulosic nano-whisker production technology from wheat straw has been developed by the Michigan Biotechnology Incorporate (MBI) International, and is expected to make biocomposites that could substitute for fiber glass and plastics in many applications, including automative parts (Liestritz, *et al.,* 2007). For the commercialization of this technology, North Dakota State University (NDSU), USA is currently engaged in a project.

Photocatalysis: One of the processes using nanoparticles is photocatalysis. The mechanism of this reaction is that when nanoparticles of specific compounds are subjected to UV light, the electrons in the outermost shell (valence electrons) are excited resulting in the formation of electron hole pairs, i.e. negative electrons and positive holes. Due to their large surface-to-volume ratio, these have very efficient rates of degradation and disinfection. As the size of the particles decrease, surface atoms are increased, which results in tremendous increase in chemical reactivity and other physico-chemical properties related to some specific conditions such as photocatalysis, photoluminescence, etc. So this process can be used for the decomposition of many toxic compounds such as pesticides, which take a long time to degrade under normal conditions. Nanoparticles can be used for the bioremediation of resistant or slowly degradable compounds like pesticides. The removal of toxins from wastewater is an emerging issue due to its effects on living organisms. Many strategies have been applied for wastewater treatment with little success. Photocatalysis can be used for purification, decontamination and deodorization of air. It has been found that semiconductor sensitized photosynthetic and photocatalytic processes can be used for the removal of organics, destruction of cancer cells, bacteria and viruses. Application of photocatalytic degradation has gained popularity in the area of wastewater treatment.

Nanobarcode technology: In our daily life, identification tags have been applied in wholesale agriculture and livestock products. Due to their small size, nanoparticles have been applied in many fields ranging from advanced biotechnology to agricultural encoding. Nanobarcodes (> 1 million) have been applied in multiplexed bioassays and general encoding because of their possibility of formation of a large number of combinations that render them attractive for this purpose. The UV lamp and optical microscope are used for the identification of micrometer-sized glass barcodes which are formed by doping with rare earth containing a specific type of pattern of different fluorescent materials. The particles to be utilized in nanobarcodes should be easily encodable, machine readable, durable, sub-micron sized taggant particles. For the manufacture of these nanobarcode particles, the process is semi-automated and highly scalable, involving the electro plating of inert metals (gold, silver, etc.) into templates defining particle diameter, and then the resulting striped nanorods from the templates are released. Nanobarcodes have been used as ID tags for multiplexed analysis of gene expression and intracellular histopathology. In the near future, more effective identification and utilization of plant gene trait resources is expected to introduce rapid and cost effective capability through advances in nanotechnology-based gene sequencing. Nanobarcodes serve as uniquely identifiable nanoscale tags and have been applied for non-biological applications such as for authentication or tracking in agricultural food and husbandry products. Such nanobarcode technology will enable one to develop new auto-ID technologies for the tagging of items previously not practical to tag with conventional barcodes. With the enhanced importance of traceability in food trade, such technologies will be helpful in promoting biosafe international food trade.

Wireless nanosensors for precision agriculture: Crop growth and field conditions like moisture level, soil fertility, temperature, crop nutrient status, insects, plant diseases, weeds, etc. can be monitored through advancement in nanotechnology. Such real-time monitoring is done by employing networks of wireless nano-sensors across the cultivated fields, providing essential data for agronomic processes like optimal time of planting and harvesting of the crops. It is also helpful for monitoring the time and amount of water application, fertilizers, pesticides, herbicides and other treatments. This has moved precision agriculture to a much higher level of control, for instance, in water usage, leading eventually to conservation of water. More precise water delivery systems are likely to be developed in the near future. The factors critical for such development include water storage, in situ water holding capacity, water distribution near roots, water absorption efficiency of plants, encapsulated water released on demand, and interaction with field intelligence through nano-sensor systems.

Nanoparticles and recycling agricultural waste: Nanotechnology is also applied to prevent waste in agriculture, particularly in the cotton industry. When cotton is processed into fabric or garment, some of the cellulose or the fibers are discarded as waste or used for low-value products such as cotton balls, yarns and cotton batting. With the use of newly-developed solvents and a technique called electrospinning, scientists produce 100 nanometer diameter fibers that can be used as a fertilizer or pesticide absorbent. These high-performance absorbents allow targeted application at desired time and location. Ethanol production from maize feedstocks has increased the global price of maize in the past two years. Cellulosic feedstocks are now regarded as a viable option for biofuels production and nanotechnology can also enhance the performance of enzymes used in the conversion of cellulose into ethanol. Scientists are working on nano-engineered enzymes that will allow simple and cost-effective conversion of cellulose from waste plant parts into ethanol. Rice husk, a rice-milling byproduct can be used as a source of renewable energy. When rice husk is burned into thermal energy or biofuel, a large amount of high-quality nano-silica is produced which can be further utilized in making other materials such as glass and concrete. Since there is a continuous source of rice husk, mass production of nano-silica through nanotechnology can alleviate the growing rice husk disposal concern.

CONCLUSION

Nanotechnology is a new science promising great potential in agriculture. The changing climate, sustainable use of natural resources, environmental factors, urbanization, agricultural waste disposal, accumulation of pesticides and over use fertilizers are the most important problems of modern agriculture. New techniques and methods have been used in order to avoid the detrimental effects of these factors. Nanotechnology clearly has the potential to dramatically impact and improve agriculture with new tools for the enhancing the ability of plants to absorb nutrients, molecular treatment of diseases, rapid disease detection, etc. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. In the near future nano structured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants.

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FERTILITY STATUS OF COTTON (*Gossypium hirsutum*) GROWING SOILS IN THIMMAJIPET MANDAL, MAHABUBNAGAR DISTRICT, TELANGANA

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ABSTRACT

Georeferenced surface soil samples (0-15 cm) collected from cotton growing fields of Thimmajipet mandal in Mahabubnagar district were analysed for pH, EC, organic carbon (OC), macronutrients (N, P, K, and S) and micronutrients (Fe, Zn, Cu and Mn). The soils were slightly to moderately alkaline, non-saline, low to medium in organic carbon, low in available N and medium to high in available P and K. High correlation between organic carbon and available nitrogen indicated that semi-arid climate induced oxidation coupled with limited litter addition led to poor accumulation of organic carbon in soils, in turn caused N deficiency, predominantly under rainfed conditions. Moreover, zinc and boron were deficient in 73 and 52 per cent of the soils, respectively, due to high pH in the soils. Integrated nutrient management with foliar application of deficient micronutrients could be viable option for enhancing cotton productivity.

KEYWORDS: Cotton growing soils, organic carbon, soil alkalinity, soil fertility.

INTRODUCTION

Cotton is the major commercial fibre crop of India. In Deccan plateau, it occupies major cultivated area and grown predominantly under rainfed conditions. This region comprises of mostly red and black associated soils and they are poor in fertility (Wani *et al*., 2009). Cotton productivity is severely limited due to poor soil fertility in general and in the cultivated fields of small and marginal farmers, in particular, due to poor resource availability. Thimmajipet mandal in Mahabubnagar district is mostly rainfed with an average annual rainfall of 500 mm and cotton occupies 60 per cent of the cultivated area mainly in the *Kharif* season. The yield level of cotton is low varying from 220 to 310 kg ha^{-1}. Though, productivity of cotton is influenced by both edaphic and non-edahpic factors, soil nutrient status and rate of fertilizer application plays a major role in deciding the yield of cotton. Information on soil fertility status of the cotton growing soils is limited in this mandal.

Hence, it is imperative to study the soil fertility status of cotton growing fields, which not only paves the way for increasing crop productivity but also sustains the cotton yields in Thimmajipet mandal.

MATERIALS AND METHODS

The study area is Thimmajipet mandal, Mahabubnagar district, located 100 km from Hyderabad. It lies between 16º 35' to 16º 44' N latitudes and 78º 07' to 78º 18' E longitudes and covers an area of 21,560 ha out of which 14,020 ha is cultivated (Vasu *et al*., 2015). A total of 214 surface soil samples (0-15 cm) were collected from cotton growing fields from the 19 villages of the mandal (Fig. 1). Soil pH, EC and organic carbon (OC) were estimated using standard procedures. Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and available P was extracted with 0.5 N $NaHCO_3$ extractant (Olsen *et al*., 1954) and extracted P was determined by ascorbic acid method (Watanabe and Olsen, 1965). Available sulphur was extracted by 0.15% $CaCl_2$ and estimated by turbidimetry (Chesnin and Yien, 1950). The DTPA extractable micronutrients such as Fe, Cu, Mn and Zn were estimated as per the procedure outlined by Lindsay and Norvell (1978). Available boron was estimated by hot water extraction method (Berger and Truog, 1939).

Based on the analytical results soil samples were categorised into low, medium and high as per the ratings proposed by Muhr *et al*. (1965) with respect to organic carbon and available N, P, and K. The available micronutrients were classified as sufficient or deficient based on critical limits of Lindsay and Norvell (1978). Nutrient indices were computed for available N, P and K (Parker *et al*., 1951). Simple correlations between various soil fertility parameters were carried out as per the procedure given by Gomez and Gomez (1984).

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Table 1. Descriptive statistics of soil fertility parameters of cotton growing soils of Thimmajipet mandal

Properties	Min	Max	Mean	Std Dev	CV
pH	6.5	9.3	7.8	0.7	8.7
EC (dS m^{-1})	0.08	1.81	0.33	0.2	80.1
OC (%)	0.1	1.6	0.9	0.3	39.5
N (kg ha^{-1})	32.5	397.7	202.6	49.4	44.1
P (kg ha^{-1})	4.3	87.6	36.6	20.5	56.0
K (kg ha^{-1})	37.0	466.8	241.4	101.3	62.7
S (mg kg^{-1})	0.4	43.4	17.0	14.5	85.2
Fe (mg kg^{-1})	2.2	56.0	17.0	12.9	76.3
Mn (mg kg^{-1})	2.8	36.2	18.1	12.2	67.3
Zn (mg kg^{-1})	0.1	3.6	0.6	0.7	110.3
Cu (mg kg^{-1})	0.1	3.0	1.2	0.8	66.9
B (mg kg^{-1})	0.1	4.2	0.6	0.5	80.0

RESULTS AND DISCUSSION

The descriptive statistics of soil fertility parameters and the variability of fertility parameters (Table 1) were interpreted using coefficient of variation (Wilding, 1985). All the parameters except pH were (Table 1) high in variability (CV > 35%). The large variability of soil nutrients could be attributed to parent material, topographic position of soils and difference in fertilizer management. Most of the cotton growing soils occur in relatively higher topographical position, therefore, soil erosion caused by slope during high intensity rainfall could have eroded the top soil along with nutrients. The high standard deviation for available N, P and K suggests that the nutrient management of the cotton growing soils was not uniform.

pH, EC and organic carbon

The soil pH varied from 6.5 to 9.3 and 24 per cent of the soil samples were neutral (6.5-7.5) and 62 per cent were slightly to moderately alkaline (7.5-9.0). The variation in pH could be attributed to nature and chemical composition of parent material. The alkaline pH of most soil samples might be due to accumulation of sodium from ground water which is high in sodium concentration (Vasu *et al.*, 2015). Electrical conductivity of all the samples were below 2 dS m^{-1} indicating non-saline nature. Organic carbon varied from 0.1 to 1.6 per cent with a mean of 0.9 per cent. However, the data in table 2 indicate that 16 per cent of the soils were low and 62 per cent were medium in organic carbon suggesting poor fertility status of the soils. The low organic carbon content could be attributed to poor crop cover, oxidation due to semi-arid climate. Since the mandal is predominantly rainfed dependent, single crop of cotton in a year is common practice due to poor resource and limited water availability. Further, poor litter addition could also be the major reason for poor organic carbon content of soils.

Available N, P, K and S

Available N varied from 32.5 to 397.7 kg ha^{-1} with 81 per cent samples showing deficiency. Available P was high in 72.4 per cent and medium in 19.6 per cent soils. Available K varied from 37 to 466.8 kg ha^{-1} and 25.2 per cent soils were low (< 140 kg ha^{-1}) in available K. The Parker nutrient index of N (1.2), P (2.6) and K (1.9) indicated that soils were acutely deficient in N, medium in K and high in P. Nitrogen management should be given due care for improving cotton yield. High P content might be due to addition of single super phosphate. The available S was (Table 3) deficient in 41 per cent of the soils.

Available Fe, Zn, Cu, Mn and B

Micronutrients zinc and boron were deficient in 73 and 52 per cent (Table 3) of soils, respectively. It indicates

Table 2. Status of organic carbon and available macronutrients

Parameters	S (mg kg^{-1})	Number of samples	Fe (mg kg^{-1})	Number of samples	Mn (mg kg^{-1})	Number of samples	Zn (mg kg^{-1})	Number of samples	Cu (mg kg^{-1})	Number of samples	B (mg kg^{-1})	Number of samples
Deficient	<10	87 (40.7)	<4.5	18 (8.4)	<1.2	0 (0)	<0.6	156 (72.9)	<0.2	5 (2.3)	<0.5	111 (51.9)
Sufficient	>10	127 (59.3)	>4.5	196 (91.6)	>1.2	214 (100)	>0.6	58 (27.1)	>0.2	209 (97.7)	>0.5	103 (48.1)

Figures in parenthesis indicate percentage of soil samples

Table 3. Status of available micronutrients

Parameters	OC (%)	Number of samples	N (kg ha^{-1})	Number of samples	P (kg ha^{-1})	Number of samples	K (kg ha^{-1})	Number of samples
Low	<0.5	36 (16.8)	<280	174 (81.3)	>11	17 (7.9)	<140	54 (25.2)
Medium	0.5-0.75	43 (20.1)	280-560	40 (18.7)	11-22	42 (19.6)	140-330	119 (55.6)
High	>0.75	135 (63.1)	>560	0 (0)	>22	155 (72.4)	>330	41 (19.2)

Figures in parenthesis indicate percentage of soil samples

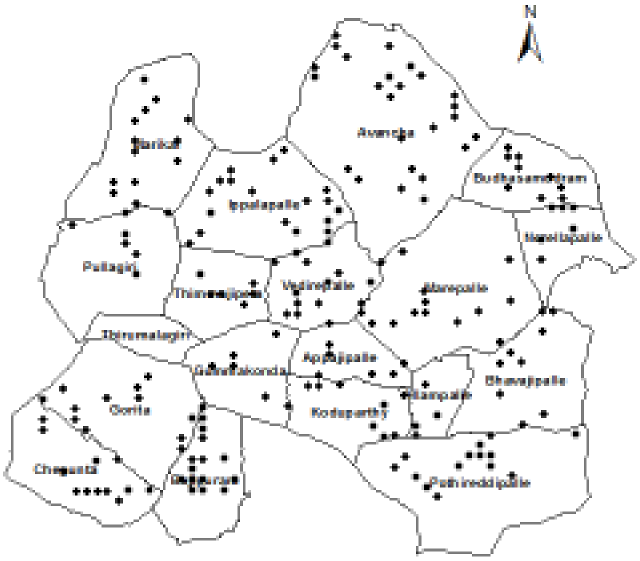

Fig. 1. Sampling locations in the cotton growing fields of Thimmajipet mandal

that multi nutrient deficiency could be one of the major factor affecting cotton productivity in Thimmajipet. Similarly Sahrawat *et al*. (2007) also reported deficiency of S, Zn and B in the farmers fields of Mahabubnagar district.

Correlations

The Pearson correlation matrix of soil fertility parameters indicated significant negative correlation between pH and micronutrients such as Z and Mn (Table 4). The deficiency of Zn was due to high pH in these soils. However, organic carbon was highly and positively correlated with available N indicating poor organic carbon content was major reason for the deficiency of N.

CONCLUSION

The cotton growing soils were slightly to moderately alkaline, non-saline, low to medium in organic carbon, low in available N and medium to high in available P and K. Parker nutrient index indicated that N management should be given due importance for better cotton productivity. The poor quality groundwater was responsible for accumulation sodium in soil, hence application of gypsum along with organic manures is highly essential to control alkalinity in these soils. Application of urea (acid forming fertilizer) along with organic manures not only enrich the N content of soils but also reduce the soil pH. Hence, integrated nutrient management is recommended to improve cotton productivity in the study area.

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Table 4. Pearson correlation coefficient of soil fertility parameters

Parameters	pH	EC	OC	N	P	K	S	Fe	Mn	Zn	Cu	B
pH	1											
EC	0.397**	1										
OC	0.243**	0.212**	1									
N	0.235**	0.264**	0.932**	1								
pH	0.001	0.027	0.178**	0.204**	1							
K	0.016	0.087	0.112	0.096	0.146*	1						
S	-0.031	0.111	0.092	0.065	-0.045	0.060	1					
Fe	-0.085	0.023	-0.061	-0.013	0.110	0.034	0.125*	1				
Mn	-0.115*	-0.021	-0.049	-0.035	0.045	0.019	0.138*	0.209**	1			
Zn	-0.131*	-0.021	0.011	0.059	-0.016	-0.003	-0.035	0.068	-0.006	1		
Cu	-0.059	0.030	0.015	0.014	0.041	0.092	0.074	0.407**	-0.023	0.019	1	
B	0.077	-0.029	0.023	0.006	-0.069	0.033	-0.021	-0.024	0.082	0.009	0.045	1

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

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VARIABILITY AND CORRELATION STUDIES IN OKRA (*Abelmoschus esculentus* L. Moench)

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ABSTRACT

A study was conducted to evaluate fourteen genotypes of okra for yield and various yield attributing traits at Vegetable Breeding Station, Agricultural Research Institute, Rajendranagar, Hyderabad during *kharif* 2006 and 2007. The data were utilized to estimate the genetic variability in terms of mean, genotypic and phenotypic coefficients of variation, heritability, expected genetic advance and expected genetic advance as per cent mean. The present investigation showed that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all traits suggesting the influence of environment in their expression. The estimates of GCV, heritability and heritability coupled with genetic advance as per cent of mean were higher for number of fruits plant^{-1}, internode length and plant height. The correlation study indicated that the yield plant^{-1} had high positive association with number of fruits plant^{-1}, plant height, internode length and fruit girth at both genotypic and phenotypic levels. Among the traits studied, number of fruits plant^{-1} had maximum direct contribution on yield and indirect contribution via plant height, internode length and fruit girth.

KEYWORDS: Correlation, genetic variability, heritability, okra, path analysis

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable crop grown for its tender fruits throughout India. It is an important protective food because of its high nutritional value which plays a pivotal role in human nutrition. Now a days, the productivity of okra shows a declining trend. In India, it occupied an area of 530.27 ha with an annual production of 6350.27 kg (National Horticulture Base data base 2012-13). Hence, developing high yielding varieties bestowed with fruits of high quantity as well as quality is of utmost importance in this crop. To improve the yield and other characters, information on genetic variability and interrelationship among different traits is necessary. The improvement in any crop is proportional to the magnitude of its genetic variability present in the population. Keeping in this in view, an attempt has been made to generate information on genetic variability, association of different characters and path analysis to select promising genotypes for utilization in okra breeding.

MATERIALS AND METHODS

A field experiment was conducted at Vegetable Breeding Station, Agricultural Research Institute, Rajendranagar, Hyderabad during *kharif* 2006 and 2007 in a randomized block design with three replications. The experimental plot size was 4 x 4 m. The experimental material consisted of fourteen okra genotypes was obtained from All India Coordinated Research Centers of Indian Council of Agricultural Research. Seeds were sown with a spacing of 45 × 30 cm. All the agronomic recommended package of practices including plant protection measures was taken up to get healthy crop. Data were recorded on randomly selected five plants from each genotype on plant height (cm), number of branches, node number at first fruit appeared, number of nodes plant^{-1}, number of fruits plant^{-1}, average fruit weight (g), fruit length (cm), fruit girth (cm) and yield plant^{-1} (g). The generated data were subjected to analysis of variance as per Panse and Sukhatme, (1987) and genotypic and phenotypic coefficients of variation according to Burton and De Vane, (1953). Heritability and genetic advance were calculated according to Johanson *et al.* (1955) and Robinson *et al.* (1949) respectively. Correlation coefficients were computed at phenotypic and genotypic levels between pairs of characters adopting the formula given by Al-Jibori *et al.* (1958) and Path coefficient of various characters was done as suggested by Wright (1956).

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RESULTS AND DISCUSSION

The extent of variability measured in terms of range, genotypic variance (Vg), phenotypic variance (Vp), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, expected genetic advance (GA) and expected genetic advance as per cent of mean were presented in Table 1. Maximum range of mean values was observed for yield plant^{-1} (101 to 296 g) while minimum range was found for fruit girth (5.77 to 6.87 cm). Among the characters, yield plant^{-1} and plant height showed wide range of variation, indicating the presence of variability for these characters and offers ample scope for selecting better genotypes. Bendale *et al.* (2003) and Hazra and Basu (2000) also reported wide range of variation for yield and plant height for other genotypes in okra. Phenotypic coefficient of variation was found to be more than genotypic coefficient of variation for all characters indicating the influence of environment on expression of the characters. These results were in agreement with that of Pathk and Singh (1999). The fruit yield plant^{-1} exhibited high phenotypic coefficient of variation estimate (31.19) followed by number of fruits plant^{-1} (26.34), internode length (25.60) and plant height (22.43) indicated that these characters were highly influenced by environmental factors. Fruit length and fruit girth recorded minimum value of phenotypic coefficient of variation compared to other characters. The genotypic coefficient of variation (GCV) would be more useful for assessing the variability since high estimates of phenotypic coefficient of variation (PCV) alone will not be enough to determine exact nature of variability. The relative magnitude of difference between PCV and GCV was low for plant height, fruit girth and yield plant^{-1} indicating the low influence of environmental factors on these characters.

The genotypic coefficient of variation along with heritability estimate would give the best scope for selection (Burton and De Vane, 1953). In the present study, the estimates of heritability varied from 0.35 to 0.89. Highest heritability values were found for plant height (0.89) followed by yield plant^{-1} (0.88) internode length (0.88) and number of fruits plant^{-1} (0.84). High heritability for these characters might be useful for plant breeder for making effective selection. Low heritability value was observed for fruit length (0.35) followed by number of nodes plant^{-1} (0.47) suggested that environmental factors constituted a major portion of total phenotypic variation and hence direct selection for these characters would not be appropriate.

Though heritability gives a useful indication of relative value of selection based on phenotypic expression, it cannot be reliable unless genetic advance under selection is not taken into consideration along with heritability (Johanson *et al.* 1955). Genetic advance as per cent mean was found to be highest for internode length (46.11) followed by number of fruits plant^{-1} (45.89) and plant height (40.97). These results suggesting the important role of genetic factors in the expression of these characters as genetic advance was estimated on the basis of heritability in broad sense (since, heritability in narrow sense give the information on additive type of gene action where the character expression was not influenced by environment). Hence, these characters would be selected on the basis of phenotypic values. According to Johanson *et al.* (1955) heritability estimate along with genetic advance is more useful than the heritability alone in predicting the resultant effect for selection. In the present investigation, high estimates of heritability accompanied with high genetic advance as per cent mean were recorded for internode length, number of fruits plant^{-1} and plant height indicating the suitability of characters for phenotypic selection. Low heritability associated with low expected genetic advance as per cent mean was observed for fruit length, and girth.

The correlation study (Table-2) revealed that the genotypic correlation coefficients were higher in magnitude than the corresponding phenotypic correlation coefficients. The results from Table 3 revealed that all the characters were positively and significantly correlated with yield plant^{-1} except node number at first fruit appeared which showed negative association with yield. Among the characters, number of fruits plant^{-1} exhibited highest positive correlation (1.035, 0.902) with yield followed by plant height (0.789, 0.748) both at genotypic and phenotypic levels and fruit girth (0.797) at genotypic level only. These results indicated that these characters can be considered for selection. These results are in confirmation with that of Bendale *et al*. (2003).

Plant height had high positive and significant correlation coefficients with internode length (0.894. 0.841), fruit girth (0.849, 0.621), number of fruits plant^{-1} (0.811, 0.711) and number of nodes plant^{-1} (0.750, 0.578) at genotypic and phenotypic levels respectively. Number of fruits plant^{-1} expressed positive correlation with plant

Table 1. Estimates of mean, range, variance components and genetic parameters for different characters

Characters	Mean ± SE	Range	CV	GCV	PCV	Heritability (broad sense)	Genetic Advance	Genetic Advance as % of mean
Plant height (cm)	87.86 ± 3.82	56.13 - 117.6	7.53	21.13	22.43	0.89	36.00	40.97
Internode length (cm)	5.66 ± 0.29	3.87 - 9.27	9.02	23.96	25.60	0.88	2.61	46.11
Node No. at 1st fruit appeared	4.63 ± 0.28	3.67 - 5.73	10.33	12.96	16.59	0.61	0.96	20.73
Number of nodes plant^{-1}	18.51± 0.83	15.20 - 21.53	7.74	7.27	10.61	0.47	1.88	9.72
Number of fruits plant^{-1}	17.74 ± 1.06	9.00 - 25.3	10.38	24.21	26.34	0.84	8.14	45.89
Average fruit weight (g)	20.04 ± 0.86	17.50 - 23.33	7.47	7.94	10.91	0.53	2.38	11.88
Fruit length (cm)	15.42 ± 0.59	14.03 - 18.20	6.67	4.90	8.28	0.35	0.92	5.97
Fruit girth (cm)	6.33 ± 0.15	5.77 - 6.87	4.13	5.00	6.32	0.58	0.52	8.21
Yield plant^{-1} (g)	197.83 ± 12.32	101.00 - 296.67	10.79	29.26	31.19	0.88	11.91	6.02

CV: Coefficient of variation; GCV: Genotypic coefficient of variation; PCV: Phenotypic coefficient of variation

Table 2. Estimates of genotypic and phenotypic correlation coefficients for different characters in Okra

Character	Level	Plant height	Internode length	Node number at 1st fruit	Number of nodes plant^{-1}	Number of fruits plant^{-1}	Avg. fruit weight	Fruit length	Fruit girth	Yield plant^{-1}
Plant height	G	1.000	0.894**	0.311*	0.750**	0.811**	0.290*	0.136	0.849**	0.798**
	P	1.000	0.841**	0.255*	0.578**	0.711**	0.148	0.111	0.621**	0.748**
Internode length	G		1.000	0.227	0.547*	0.807**	0.429*	0.189	0.850**	0.789**
	P		1.000	0.209	0.469*	0.693**	0.303*	0.096	0.661**	0.747**
Node number at 1st fruit	G			1.000	0.555*	0.007	-0.184	-0.413*	-0.023	-0.015
	P			1.000	0.392*	0.017	-0.098	-0.038	-0.020	-0.014
Number of nodes plant^{-1}	G				1.000	0.392*	0.139	-0.304*	0.420*	0.407*
	P				1.000	0.275*	0.079	-0.024	0.213	0.297*
Number of fruits plant^{-1}	G					1.000	0.212	0.260*	0.763**	1.035**
	P					1.000	0.164	0.237	0.578**	0.902**
Average fruit weight	G						1.000	0.595**	0.453*	0.306*
	P						1.000	0.457*	0.416*	0.284*
Fruit length	G							1.000	0.609**	0.390*
	P							1.000	0.329*	0.193
Fruit girth	G								1.000	0.797**
	P								1.000	0.662**
Yield plant^{-1}	G									1.000
	P									1.000

*, ** Significant at 0.05% and 0.01% probability respectively; G, P: Genotypic and Phenotypic Coefficient of correlation

Table 3. Estimates of direct and indirect effects of yield and yield related characters in Okra

Character	Level	Plant height	Internode length	Node number at 1st fruit	Number of nodes plant^{-1}	Number of fruits plant^{-1}	Avg. fruit weight	Fruit length	Fruit girth	Correlation with yield
Plant height	G	**-0.245**	-0.403	-0.003	0.073	1.148	-0.004	0.022	-0.028	0.876
	P	**0.172**	-0.013	-0.004	-0.015	0.405	0.014	-0.005	0.024	0.766
Internode length	G	-0.216	**-0.458**	-0.003	0.085	1.009	-0.018	0.047	-0.029	0.789
	P	0.127	**-0.018**	-0.006	-0.020	0.401	0.042	-0.006	0.026	0.747
Node number at 1st fruit	G	-0.056	-0.104	**-0.013**	0.087	0.008	0.008	-0.104	-0.000	-0.015
	P	0.026	-0.004	**-0.028**	-0.017	0.010	-0.014	0.003	-0.001	0.014
Number of nodes plant^{-1}	G	-0.115	-0.251	-0.007	**0.156**	0.490	-0.006	-0.076	-0.014	0.407
	P	0.060	-0.008	-0.011	**-0.043**	0.159	0.011	-0.002	0.008	0.297
Number of fruits plant^{-1}	G	-0.225	-0.370	-0.000	0.061	**1.251**	-0.001	0.065	-0.026	0.662
	P	0.120	-0.12	-0.001	-0.012	**0.578**	0.023	-0.016	0.023	1.035
Average fruit weight	G	-0.022	-0.197	0.002	0.022	0.266	**-0.043**	0.149	-0.015	0.306
	P	0.017	-0.005	0.003	-0.003	0.095	**0.140**	-0.030	0.017	0.284
Fruit length	G	-0.021	-0.087	0.005	-0.048	0.325	-0.025	**0.251**	-0.021	0.390
	P	0.014	-0.002	0.001	-0.001	0.137	0.064	**-0.066**	0.013	0.193
Fruit girth	G	-0.200	-0.390	-0.000	0.066	0.954	-0.019	0.153	**-0.034**	0.193
	P	0.106	-0.012	0.001	-0.009	0.334	0.058	-0.022	**0.040**	0.797

height (0.811, 0.711) and fruit girth (0.763, 0.578) at both genotypic and phenotypic levels. Fruit length had positive association with fruit girth at genotypic level (0.609) and phenotypic (0.329) level. These findings suggested that these traits should be considered during direct selection for genetic improvement for yield in okra. Dhall *et al.* (2000) also reported similar association among for these characters.

Path coefficient analysis studies revealed that number of fruits plant^{-1} showed the highest positive effect (1.251) on yield plant^{-1} (Table 3). Among the characters studied, all the traits showed positive direct effect on yield except internode length which showed negative direct effect on yield plant^{-1}. The highest indirect effect of number of fruits plant^{-1} was observed with plant height (1.148), internode length (1.009) followed by fruit girth (0.954). These characters also showed significant positive correlation with yield. These findings indicating that direct selection for these traits might be effective and there is possibility of improving yield plant^{-1}. Similar results have been reported by Nasit *et al.* (2010) and Mehta *et al.* (2006).

The above findings suggested that for getting higher yield, selection should be practiced for yield related traits giving equal importance to number of fruits, number of nodes, plant height and the selected genotypes may be tested under potential areas for identification of best cultivar either for general cultivation or for using in future breeding programme.

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YIELD AND NUTRIENT UPTAKE OF MAIZE AS INFLUENCED BY DRIP IRRIGATION AND NITROGEN LEVELS

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ABSTRACT

A field study was conducted during *rabi* seasons of 2013-14 and 2014-15 at S.V. Agricultural College, Tirupati. The field experiments laid out in spilt plot design, replicated thrice by taking irrigation schedules (surface drip irrigation at 0.7, 0.8 and 0.9 IW/CPE ratios and weekly check basin irrigation) as main plots and nitrogen levels (160, 200 and 240 kg ha^{-1}) as sub plots. The higher dry matter, kernel and stover yields and nutrient uptake by maize was found to be the highest when irrigations were scheduled at weekly intervals by check basin method, which was on par to that of drip irrigation at 0.9 IW/CPE ratio. As regards to nitrogen levels tried, all the parameters were found to be superior with the nitrogen dose of 240 kg N ha^{-1}. The interaction between the irrigation schedules and nitrogen levels indicated that higher yields and nutrient uptake was recorded with scheduling irrigation either at weekly intervals through check basin method or by drip irrigation at 0.9 IW/CPE ratio along with 240 kg N ha^{-1}. The experimental results concluded that maize crop can be grown economically at 0.9 IW/CPE ratio through surface drip irrigation with 240 kg N ha^{-1}.

KEYWORDS: Maize, Drip irrigation, Grain yield, Nutrient uptake

Maize is a multipurpose crop, which can supply food, feed and fuel in relatively large quantities as compared to other cereal crops. It has the highest average yield per hectare and stands third after wheat and rice in area and total production in the world. Though, the crop is mainly grown as rainfed crop during *kharif*, it is also being cultivated as irrigated crop during *rabi*. The shortage of water resources is a worldwide problem and the phenomenon of water stress is very obvious. Proper growth and development of maize needs favorable soil moisture in root zone. The moisture content in the soil gradually decreases with the passing of time during dry season. Limited water supply during the growing season results in soil and plant water deficits and reduces maize yields. With drip irrigation the water is delivered slowly and constantly, creating the ideal balance of water and oxygen in the rhizosphere and benefiting the maize plants which dislike over-compacted soil. In this particular study, the concept of IW/CPE ratio which is a reliable, economical and practical method for scheduling of irrigation as suggested by Prihar *et al.* (1976) has been adopted.

Nitrogen has a dominant role in plant physiology as it is an integral part of protoplasm, chlorophyll, proteins, enzymes, amino acids and nucleic acids. Optimum application of nitrogen is a pre-requisite for production of maize. Not only the grain yield of maize, but the quality of grains is also affected to a great extent by nitrogen availability. It has been reported that grain yield of maize gets increased by N application (Tafteh and Sepaskhah, 2012). For this purpose, maize was grown under different combinations of irrigation schedules and nitrogen levels and the study was focused on irrigation and nitrogen management impacts on maize yield and nutrient uptake.

MATERIAL AND METHODS

The present investigation carried out during two consecutive *rabi* seasons of 2013-14 and 2014-15 on sandy clay loam soils of S.V. Agricultural College farm, Tirupati campus of Acharya NG Ranga Agricultural University of Andhra Pradesh. The soil was sandy loam in texture, neutral in reaction, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium, during both the years of study. The field experiment was laid out with maize crop in a split plot design with three replications, by taking irrigation schedules (surface drip irrigation at 0.7, 0.8 and 0.9 IW/CPE ratios and weekly check basin irrigation) as main plots and nitrogen levels (160, 200 and 240 kg ha^{-1}) as sub plots. The test variety of maize "DHM-117" was

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sown at 60/30 × 20 cm (paired row planting) and nitrogen was applied as per the treatments in three splits *i.e.,* half at basal, one fourth at knee high stage and remaining one fourth at taselling stage, whereas, recommended dose of phosphorous and potassium each of @ 80 kg ha^{-1} was applied basally to entire crop. The irrigation water through surface drip irrigation was delivered through in line emitters, spaced at 40 cm apart with a discharge rate of 4 l hr^{-1}. Treatments were imposed strictly as per the plan and the quantity of water applied to each plot was determined by considering number of laterals, emitter spacing and discharge rate. The total depth of water applied at different IW/CPE ratios was kept same.

RESULTS AND DISCUSSION

Dry matter production

During both the years of study, dry matter production was significantly higher with the irrigation at weekly intervals in check basin, which was statistically on par with that of drip irrigation at 0.9 IW/CPE ratio (Table 1). This might be attributed to more nutrient mobility coupled with higher water uptake under frequent irrigation regime which might have increased the photosynthetic activity and LAI inturn enhancing the dry weight of plant (Aulakh *et al*., 2013). These results are in agreement with those of Reddy and Padmaja (2014). The lowest dry matter production was recorded with drip irrigation at 0.7 IW/CPE ratio.

Application of nitrogen at 240 kg ha^{-1} was found to be the highest with respect to dry matter production, which was distinctly superior to that of 200 kg ha^{-1}, where as the lowest dry matter production was obtained with 160 kg ha^{-1} , during both the years. This indicated the positive effect of nitrogen in boosting the crop growth. Terman *et al.* (1977) also observed that application of nitrogen increased the plant height by increasing length and number of internodes, leaf number and size resulting in increased photosynthetic apparatus by increasing total leaf area of the crop consequently enhanced the assimilates production. This has direct bearing on dry matter production $plant^{-1}$ and unit $area^{-1}$. Mansouri-Far *et al.* (2010) quoted that LAI and leaf greenness determine the capture and use efficiency of solar radiation by maize plant and thereby affecting the conversion rate of available radiation to dry matter accumulation. The interaction between the IW/CPE ratio and nitrogen levels was significant in affecting the drymatter production of main crop.

Yield

Different drip irrigation schedules, nitrogen levels and their interaction significantly influenced the kernel and stover yields of maize, during both the years (Table 2).

The kernel and stover yields were significantly higher with scheduling irrigation conventionally at weekly intervals in check basin, which were on par with the yields obtained under drip irrigation at 0.9 IW/CPE ratio. This can be attributed to the fact that frequent irrigations provides adequate moisture in the surface layer, in which most of maize roots exists. This resulted in better crop growth and yield attributes consequently higher yield. Similar results were also quoted by Elzubeir and Mohamed (2011). Increase in kernel yield under drip irrigation at 0.9 IW/CPE was mainly due to increased soil moisture in the upper 30 cm soil layer leading to higher plant relative water content and less negative leaf water potential as quoted by Viswanatha *et al.* (2002). These results are in conformity with the findings of Aulakh *et al.* (2013). Significantly, the lowest kernel and straw yield was noticed under irrigation schedule of 0.7 IW/CPE ratio through drip, during both the years of study.

Maize fertilized with 240 kg N ha^{-1} significantly produced the highest kernel and stover yields over rest of the tried nitrogen levels i.e 200 and 160 kg ha^{-1}. This might be due to favourable effect at higher nitrogen level leading to better crop growth and increase in yield attributes which was reflected in kernel yield of maize. In physiological terms, the grain yield of maize is largely governed by source and sink relationships as it is directly related to nitrogen. These results are in accordance with the findings of Mala (2008). The lowest kernel and stover yield was registered with the application of nitrogen at 160 kg ha^{-1}, during both the years due to reduced availability of nitrogen as per the plant requirements.

Interaction between conventional irrigation at weekly intervals in check basin method along with 240 kg N ha^{-1} resulted in the highest yields of kernel and stover followed by drip irrigation at 0.9 IW/CPE ratio in combination with same level of nitrogen. This might be due to the better availability of nutrients under higher soil moisture and at high nitrogen available conditions, which might have increased the crop growth and better translocation of photosynthates from source to sink. Similar evidence on complementary use of moisture and nitrogen was reported by Patil *et al.* (2012). Combination of drip irrigation at

Table 1. Dry matter and nutrient uptake of maize at harvest as influenced by drip irrigation and nitrogen levels

Treatments	Dry matter production (kg ha^{-1})		Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Drip irrigation schedules								
0.7 IW/CPE	6263	6712	72.2	74.3	26.7	27.3	143.0	147.5
0.8 IW/CPE	9247	9734	87.6	89.8	29.1	30.3	154.9	159.2
0.9 IW/CPE	10965	11022	110.7	112.9	31.2	32.3	171.6	176.4
Weekly check basin	11087	11269	116.6	120.0	32.0	33.7	173.2	177.8
CD (p= 0.05)	518	304	7.9	8.6	1.3	1.6	5.6	4.0
Nitrogen levels								
160	8964	8860	87.7	90.1	28.5	29.7	154.0	159.2
200	9467	9964	99.3	101.7	29.8	30.9	160.6	165.0
240	9740	10229	103.5	106.0	30.9	32.2	166.9	171.5
CD (p= 0.05)	131	198	3.6	3.6	0.5	0.7	NS	NS

Table 2. Kernel yield stover yield (kg ha^{-1}) of maize as influenced by drip irrigation and nitrogen levels

Drip irrigation schedules	Grain yield								Stover yield							
	2013-14				2014-15				2013-14				2014-15			
	Nitrogen (kg ha^{-1})				Nitrogen (kg ha^{-1})				Nitrogen (kg ha^{-1})				Nitrogen (kg ha^{-1})			
	160	200	240	Mean	160	200	240	Mean	160	200	240	Mean	160	200	240	Mean
0.7 IW/CPE	2073	2743	2929	2582	2339	2763	3049	2717	2458	3635	4078	3390	2897	3714	4298	3636
0.8 IW/CPE	3063	4065	4194	3774	3101	4103	4236	3813	3920	5812	6333	5355	4035	5852	7026	5637
0.9 IW/CPE	3759	4907	5051	4572	3723	4838	5015	4525	5059	7420	8095	6858	5094	7301	8079	6825
Weekly check basin	3813	4948	5128	4630	3992	4976	5204	4724	5383	7945	8700	7343	5702	7929	8911	7514
Mean	3177	4166	4326		3289	4170	4376		4205	6203	6801		4432	6199	7078	
	CD (P=0.05)				**CD (P=0.05)**				**CD (P=0.05)**				**CD (P=0.05)**			
Irrigation (I)	453				498				671				784			
Nitrogen (N)	102				122				158				364			
I at N	482				536				718				982			
N at I	234				278				360				797			

0.7 IW/CPE ratio with the lowest nitrogen level of 160 kg ha^{-1} recorded significantly the lowest kernel and stover yields, during both the years of study, due to limited availability of moisture and nitrogen to the crop.

NUTRIENT UPTAKE BY MAIZE

Nitrogen uptake

Irrigation schedules and nitrogen levels as well as their interaction significantly influenced the nutrient uptake of maize at harvest with unaltered trend, during both the years of study.

The highest nitrogen uptake (Table 1) was noticed with scheduling of irrigation conventionally at weekly intervals through check basin method, which was on par with drip irrigation at 0.9 IW/CPE ratio and significantly superior over drip irrigation at 0.8 IW/CPE ratio. The lowest nitrogen uptake was recorded with drip irrigation scheduled at 0.7 IW/CPE ratio, during both the years. Increase in irrigation frequency increased the nitrogen uptake due to the increased mobility of nitrogen with increase in soil moisture content, resulting in increased availability of nitrogen, which finally increased the uptake of nitrogen. These results are in conformity with the findings of Reddy and Padmaja (2014).

During both the years of investigation, application of nitrogen at 240 kg ha^{-1} recorded significantly higher nitrogen uptake by maize than at 200 kg N ha^{-1}, where as the lowest nitrogen uptake was noticed with application of nitrogen at 160 kg ha^{-1}. Uptake of nitrogen increased significantly with each successive increment in nitrogen which might be due to increased root cation exchange capacity, which might have enhanced the absorption of entire dose of applied nitrogen (Mala, 2008).

Phosphorus and potassium uptake

Irrigation schedules and nitrogen levels differed conspicuously with respect to phosphorus and potassium uptake of maize at harvest and showed similar trend, during both the years of study (Table 1). Maize irrigated at weekly intervals by check basin method registered significantly the higher phosphorus and potassium uptake, which inturn was on par with drip irrigation at 0.9 IW/CPE ratio and both of them were distinctly superior to that resulted with drip irrigation at 0.8 IW/CPE ratio. Drip irrigation scheduled at 0.7 IW/CPE resulted in the lower phosphorus and potassium uptake.

Phosphorus and potassium uptake of maize was significantly higher with the application of nitrogen at 240 kg ha^{-1} than that obtained with 200 kg N ha^{-1}. Crop fertilized with 160 kg N ha^{-1} showed the lower phosphorus and potassium uptake in both the years. The increased uptake of phosphorus and potassium might be due to the fact that increased supply of nitrogen might have increased the root growth, leading to explore more soil volume for absorption of nutrients. These results are in agreement with the findings of Sobhana *et al.* (2013).

CONCLUSION

Based on the outcome of the investigation, it could be inferred that for maximizing the maize kernel yield and nutrient uptake, weekly irrigation by check basin method was optimum. But under the conditions of limited water availability, surface drip irrigation scheduled at 0.9 IW/CPE ratio with 240 kg N ha^{-1} was optimum for high productivity of *rabi* maize in Southern Agro Climatic Zone of Andhra Pradesh.

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MANAGEMENT OF FOLIAR BLIGHT (*Alternaria Chrysanthemi*) OF CHRYSANTHEMUM

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ABSTRACT

Field experiments were carried out for three consecutive years *i.e.* 2009-2010, 2010-2011 and 2011-2012 at Horticultural College and Research Institute, Anantharajupeta, to study the effect of different fungicides for the management of foliar blight of chrysanthemum. Among different fungicides tested, tebuconazole @ 0.1% recorded lowest per cent disease index (PDI) and highest flower yield followed by propiconazole @ 0.1% and azoxystrobin @ 0.075%. The PDI was highest with lowest flower yield in control. In other fungicides PDI was in the range of 26.66 - 31.10. The B : C ratio of tebuconazole, propiconazole and azoxystrobin was 5.55, 4.56 and 4.19 respectively.

KEYWORDS: Chrysanthemum, Foliar blight, *Alternaria*, Management

INTRODUCTION

Chrysanthemum is one of the oldest flowering plants, commercially grown in different parts of the world. It is important both as cut flower and as potted plant in the international market. There has been constant demand for chrysanthemum flowers particularly from European markets during winter months and throughout the year in our country. However, it is not possible to produce quality cut flowers all the year round under open field conditions. For these several factors have been identified in India. The most important factors identified are, the diseases like alternaria leaf blight, septoria leaf spot, rust, wilt, bacterial blight and non availability of leading varieties which are resistant to biotic and abiotic stresses. Among several diseases, alternaria leaf blight caused by A*lternaria chrysanthemi* (Simmons, 1965) is most destructive and cause heavy losses under field as well as market conditions (Kumar, 2008).

Generally, farmers use fungicides like mancozeb and carbendazim, but with the use of same fungicides repeatedly there is a possibility of development of tolerance in pathogens. So it is essential to identify and test new alternate fungicides other than regularly used fungicides to avoid resistance in pathogens so that farmers can reap good harvest with export quality.

MATERIALS AND METHODS

A field experiment was carried out for three consecutive years during 2009-10, 2010-11 and 2011-2012 at Horticultural College and Research Institute, Anantharajupeta, Kadapa district to assess the efficacy of different fungicides for the control of Alternaria blight of chrysanthemum under natural field conditions. The experiments were laid out in Randomized Block Design with three replications. The experiment comprised seven treatments *viz*., chlorothalonil (0.2%) captan (0.2%) azoxystrobin (0.075%), propiconazole (0.1%), tebuconazole (0.1%) and benomyl (0.1%) and untreated check served as control. The chrysanthemum crop was raised and maintained by following recommended package of practices. Each fungicide was sprayed 4 times starting from the appearance of disease in the field at 15 days interval. Data pertaining to the disease severity and flower yield were recorded. Ten plants were examined randomly and scored for disease severity by following 0-5 scale (Kumar *et al*., 2011). The details of scale are shown below.

0- No disease symptoms.

1- A few spots towards tip covering 10 per cent leaf area.

2- Several dark brown patches covering up to 20 per cent leaf area

3- Several patches with paler outer zone covering up to 40 per cent leaf area

4- Covering up to 40 percent leaf area

5- Complete drying of the leaves or breaking of the leaves from center.

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Table 1. Effect of different fungicides on *Alternaria* blight disease of chrysanthemum

Treatments	Per cent Disease Index (PDI)			
	2009-2010	2010-2011	2011-2012	Mean
Chlorothalonil (0.2%)	26.7 (31.1)	28.3 (32.1)	24.9 (29.9)	26.6 (31.0)
Captan (0.2%)	29.3 (32.8)	31.3 (34.0)	26.8 (31.2)	29.2 (32.7)
Azoxystrobin (0.075%)	16.6 (24.1)	19.3 (26.0)	12.7 (20.9)	16.24 (23.7)
Propiconazole (0.1%)	16.6 (24.0)	18.0 (25.1)	11.7 (20.0)	15.48 (23.1)
Tebuconazole (0.1%)	5.90 (14.0)	6.0 (14.1)	6.2 (14.5)	6.06 (14.2)
Benomyl (0.1%)	31.7 (34.2)	31.9 (34.4)	29.6 (33.0)	31.1 (33.8)
Control	52.5 (46.4)	58.3 (49.8)	40.9 (39.7)	50.6 (45.3)
SEm ±	0.5	0.5	0.3	1.0
CD at 5% level	1.5	1.7	1.0	3.0

Figures in parentheses are angular transformed value

Table 2. Effect of different fungicides on flower yield of chrysanthemum

Treatments	Flower yield (q/ha)			
	2009-2010	2010-2011	2011-2012	Mean
Chlorothalonil (0.2%)	50.7	48.4	49.4	49.5
Captan (0.2%)	52.3	43.5	40.3	47.4
Azoxystrobin (0.075%)	69.7	54.9	50.2	58.3
Propiconazole (0.1%)	67.2	57.3	54.0	59.5
Tebuconazole (0.1%)	78.4	71.8	70.2	73.4
Benomyl (0.1%)	48.6	39.6	44.9	44.4
Control	37.3	31.0	30.7	33.0
SEm±	0.6	0.9	0.7	1.8
CD at 5% level	2.0	2.6	2.2	5.4

Table 3. Economic analysis of management of *Alternaria* leaf blight of Chrysanthemum

Treatments	Yield	B:C ratio
Chlorothalonil (0.2%)	49.5	3.4
Captan (0.2%)	45.4	3.5
Azoxystrobin (0.075%)	58.3	4.1
Propiconazole (0.1%)	59.5	4.5
Tebuconazole (0.1%)	73.4	5.5
Benomyl (0.1%)	44.4	3.4
Control	33.0	2.6

Per cent Disease Index (PDI) was calculated by using the following formula (Wheeler, 1969).

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves examined}} \times \frac{100}{\text{Maximum grade value}}$$

Economic analysis: B: C ratio was obtained by calculating the extra income (benefit) and the additional cost of application of fungicides and other costs based on market prices of inputs.

RESULTS AND DISCUSSION

Foliar blight disease

During first year of experimentation (2009-10) the lowest PDI of 5.90 was recorded in tebuconazole sprayed plots followed by propiconazole (16.62) and azoxystrobin (16.68). The highest PDI of 52.58 was recorded in control plot. With regard to other fungicides the PDI recorded was in the range of 26.70 to 31.70. In second and third year also, the highest PDI was recorded in control plot (58.37 and 40.93) and the lowest was recorded with tebuconazole (6.00 and 6.28) followed by propiconazole (18.05 and 19.30) and azoxystrobin (11.78 and 12.76) (Table.1). The mean data of three years in terms of PDI showed that the lowest PDI of 6.06 was recorded in tebuconazole treated plots and was significantly superior to all other treatments in reducing the disease severity. This was followed by propiconazole (15.48) and azoxystrobin (16.24). The highest PDI was recorded in control plot (50.62). Based on the results achieved, the fungicides may be arranged as tebuconazole, propiconazole, azoxystrobin, chlorothalonil, captan and benomyl in order of their efficacy in managing foliar blight of chrysanthemum.

Flower yield

In the first year, the flower yield was recorded in the range of 37.35 to 78.42 q ha^{-1}. The highest flower yield was recorded in tebuconazole (78.42 q ha^{-1}) treated plot and lowest was recorded in control plot (37.35 q ha^{-1}). During second year, and third year also tebuconazole gave the highest flower yield (71.80 and 70.26 q ha^{-1}) with lowest PDI. The pooled data of three years revealed that tebuconazole was effective in increasing flower yield (73.49 q ha^{-1}) by minimizing the foliar blight (6.06 PDI) disease (Table 1 and 2) .

The economic analysis of data (Table 3) revealed that tebuconazole recorded highest B: C ratio (5.55) with lowest percent disease index (6.06) and highest flower yield (73.49 q ha^{-1}) followed by propiconazole and azoxystrobin (4.56 and 4.19 B : C ratio, respectively)

Based on the observations made during three years of experimentation, foliar blight of chrysanthemum caused by *Alternaria chrysanthemi* could be effectively controlled by tebuconazole which recorded lowest PDI and highest flower yield. Next to this was propiconazole and azoxystrobin compared to the other fungicides. These results are in agreement with the findings of Mesta *et al.,* (2003) who reported that the triazole fungicides are the effective fungicides to alternaria leaf blights. Villanueva-couoh *et al.* (2005) reported that treatment of chrysanthemum with azoxystrobin reduced the epidemological intensity of the disease by 50% and showed the lowest level of apparent infection. Kumar *et al.* (2008) revealed that propiconazole and hexaconazole fungicides completely inhibited the mycelial growth of *Alternaria alternata* causing leaf blight in chrysanthemum under laboratory conditions. Kamanna *et al.*,(2010) reported that three sprays of chlorothalonil @ 0.2% sprayed at an interval of 15 days starting from the onset of disease symptoms can effectively control the leaf blight of chrysanthemum caused by *Alternaria alternata.* So based on the results these fungicides are more effective in controlling foliar blight in chrysanthemum.

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COMPATIBILITY STUDIES OF CERTAIN NEW PESTICIDES IN THE MANAGEMENT OF LEAF FOLDER AND LEAF BLAST IN RICE

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ABSTRACT

Five insecticides and three fungicides at recommended concentrations were evaluated as tank mix in various insecticide and fungicide combinations for their efficacy against leaf folder and leaf blast in rice. Among the different combinations tested no phytotoxic symptoms were observed indicating that all the combinations are safe to the rice crop. The chemical compatibility of insecticide and fungicide combinations measured through the bioefficacy studies under field conditions revealed that the insecticides, flubendiamide @ 0.1 mL L^{-1} (5.79%) and chlorantraniliprole @ 0.3 mL L^{-1} (5.8%) were highly effective against leaf folder and their combination with fungicide in no way undermined the efficacy when mixed indicating their compatibility. Similarly the fungicide tricyclazole @ 0.6 g l^{-1} was highly effective against leaf blast alone and in combination with other insecticides with per cent disease index of 11.0. Thus all the insecticides and fungicides used in the present investigation are compatible with each other and can be safely combined as tank mix for control of rice pests.

KEYWORDS:

INTRODUCTION

Rice (*Oryza sativa* L) the staple food crop of Asian and developing countries feeding more than 2 billion people. India is the second largest rice producing country in the world. Rice of late was subjected to attack by more than 300 species of insect pests and many diseases at various stages of crop growth (Pasalu and Katti, 2006). In Southern zone of Andhra Pradesh, leaf folder and leaf blast occur at the same stage of crop growth. Therefore farmers are regularly going for combination of insecticides and fungicides for reducing labour cost, labour shortage and as a measure of economy. Keeping this in view, the present study was undertaken with certain new insecticides and most commonly used fungicides to find their efficacy on leaf folder and leaf blast as well as for testing the compatibility.

MATERIALS AND METHODS

The experiments were conducted during *rabi* 2012-13 and *rabi* 2013-14 in randomized block design (RBD) at Agricultural Research Station, Nellore. Five insecticides namely flubendiamide 480 SC @ 0.1 mL L^{-1} and chlorantraniliprole 20 SC @ 0.3 mL L^{-1}, cartap hydrochloride 50 SP @ 2.0 g l^{-1}, buprofezin 25 SC @ 2.0 mL L^{-1} and profenophos 50 EC @ 2.0 mL L^{-1} and three fungicides tricyclazole 75 WP @ 0.6 g l^{-1}, hexaconazole 5 EC @ 2.0 mL L^{-1} and propiconazole 25 EC @ 1.0 mL L^{-1} were evaluated as tank mix of insecticide and fungicide combinations for their efficacy against leaf folder as well as leaf blast and to investigate their compatibility as tank mix application. An untreated control was maintained for comparison sake. Popular susceptible rice variety Samba mashuri (BPT 5204) was selected for the study and grown as per the recommended package of practices.

Population counts of rice leaf folder or webbed leaves were recorded in 10 marked hills per plot one day before spraying and 7 Days After Spraying (DAS).

The Per cent Disease Index (PDI) of leaf blast was recorded as per the Standard Evaluation System (SES) for Rice (IRRI, 1996). The grain yield was recorded from each net plot and calculated to kg ha^{-1}. The data was subjected to statistical analysis. Symptoms of phytotoxicity if any was also recorded at 1, 3, 5, 7 and 10 days after imposition of treatments.

RESULTS AND DISCUSSION

During *Rabi,* 2012-13 the first spraying was given against leaf folder at 60 DAT and the mean population of leaf folder by way of leaf folder damage ranged from 31.66% to 33.16%. The mean per cent infested leaves

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Table 1. Efficacy of insecticides and fungicides as tank mix against leaf folder in rice during *rabi*, 2012-13 and 2013-14

S. No.	Treatments	Dosage (g or mL/L)	Leaf folder infested leaves/hill						Yield (kg/ha)		
			Before spray			7 DAS					
			2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_{1}	Flubendiamide 480 SC	0.1	31.70 (34.24)	31.78 (34.28)	31.7 (34.28)	1.01 (5.77)	1.03 (5.76)	1.0 (5.79)	4098	4151	4125
T_{2}	Chlorantraniliprole 20 SC	0.3	31.84 (34.33)	32.28 (34.60)	32.1 (34.47)	1.01 (5.75)	1.09 (5.60)	1.0 (5.80)	4202	4252	4227
T_{3}	Cartap hydrochloride 50 SP	2.0	32.19 (34.55)	31.99 (34.43)	32.1 (34.49)	9.45 (17.77)	11.42 (19.73)	10.4 (18.83)	3699	3752	3725
T_{4}	Buprofezin 25 SC	2.0	31.92 (34.37)	32.35 (34.65)	32.1 (34.51)	39.70 (39.04)	39.15 (38.71)	39.4 (38.87)	2598	2651	2625
T_{5}	Profenophos 50 EC	2.0	31.89 (34.36)	32.29 (34.61)	32.1 (34.49)	17.43 (24.66)	17.65 (24.83)	17.5 (24.75)	3499	3548	3524
T_{6}	Tricyclazole 75 WP	0.6	31.74 (34.27)	32.52 (34.75)	32.1 (34.51)	37.30 (37.61)	39.43 (38.87)	38.4 (38.24)	2799	2851	2825
T_{7}	Hexaconazole 5 EC	2.0	31.98 (34.42)	32.37 (34.66)	32.2 (34.55)	33.87 (35.50)	38.84 (38.52)	36.4 (37.03)	2801	2854	2828
T_{8}	Propiconazole 25 EC	1.0	31.72 (34.25)	32.40 (34.68)	32.1 (34.47)	37.73 (37.86)	39.23 (38.75)	38.5 (38.32)	2801	2851	2826
T_{9}	Flubendiamide + Tricyclazole	0.1 + 0.6	31.98 (34.42)	32.36 (34.65)	32.2 (34.53)	1.02 (5.73)	1.18 (5.89)	1.1 (5.86)	4151	4152	4152
T_{10}	Flubendiamide + Hexaconazole	0.1 + 2.0	31.89 (34.36)	30.20 (33.32)	31.0 (33.84)	1.01 (5.55)	0.98 (5.62)	1.0 (5.59)	4152	4265	4209
T_{11}	Flubendiamide + Propiconazole	0.1 + 1.0	33.16 (35.15)	32.16 (34.53)	32.7 (34.84)	1.09 (5.85)	1.05 (5.86)	1.1 (5.89)	4148	4199	4174
T_{12}	Chlorantraniliprole + Tricyclazole	0.3 + 0.6	31.73 (34.26)	32.20 (34.56)	32.0 (34.42)	1.04 (5.49)	1.01 (5.69)	1.0 (5.76)	4246	4301	4274
T_{13}	Chlorantraniliprole + Hexaconazole	0.3 + 2.0	31.92 (34.37)	33.25 (35.17)	32.6 (34.79)	0.99 (5.73)	1.09 (5.92)	1.0 (5.84)	4250	4302	4276
T_{14}	Chlorantraniliprole + Propiconazole	0.3 + 1.0	31.81 (34.31)	29.03 (32.57)	30.4 (33.46)	1.00 (5.74)	0.91 (5.36)	1.0 (5.58)	4252	4301	4276
T_{15}	Cartap hydrochloride + Tricyclazole	2.0 + 0.6	32.11 (34.49)	30.88 (33.68)	31.5 (34.10)	11.36 (19.69)	11.10 (19.32)	11.2 (19.54)	3751	3794	3772
T_{16}	Cartap hydrochloride + Hexaconazole	2.0 + 2.0	31.66 (34.22)	28.25 (31.91)	30.0 (33.15)	10.99 (19.23)	10.07 (18.48)	10.5 (18.87)	3751	3801	3776
T_{17}	Cartap hydrochloride + Propiconazole	2.0 + 1.0	31.87 (34.35)	28.27 (32.10)	30.1 (33.24)	11.33 (19.58)	10.14 (18.54)	10.7 (19.07)	3752	3800	3776
T_{18}	Buprofezin + Tricyclazole	2.0 + 0.6	32.03 (34.44)	36.70 (37.23)	34.4 (35.85)	37.48 (37.71)	41.98 (40.35)	39.7 (39.04)	2800	2849	2825
T_{19}	Buprofezin + Hexaconazole	2.0 + 2.0	32.02 (34.44)	34.59 (35.95)	33.3 (35.21)	37.57 (37.76)	40.20 (39.29)	38.9 (38.53)	2801	2850	2825
T_{20}	Buprofezin + Propiconazole	2.0 + 1.0	32.06 (34.46)	31.17 (33.87)	31.6 (34.16)	38.39 (38.25)	40.19 (39.29)	39.3 (38.78)	2800	2850	2825
T_{21}	Profenophos + Tricyclazole	2.0 + 0.6	31.94 (34.39)	31.56 (34.13)	31.8 (34.26)	17.46 (24.68)	18.54 (25.46)	18.0 (25.09)	3548	3601	3575
T_{22}	Profenophos + Hexaconazole	2.0 + 2.0	31.82 (34.32)	32.28 (34.61)	32.0 (34.46)	17.43 (24.66)	18.13 (25.19)	17.8 (24.93)	3551	3601	3576
T_{23}	Profenophos + Propiconazole	2.0 + 1.0	32.06 (34.46)	29.38 (32.80)	30.7 (33.64)	17.50 (24.71)	16.64 (24.04)	17.1 (24.38)	3549	3601	3575
T_{24}	Untreated control	--	31.99 (34.42)	28.87 (32.40)	30.4 (33.43)	37.63 (37.81)	38.32 (38.18)	38.0 (37.99)	2398	2499	2449
	CD		NS	NS	NS	3.06	3.38	2.69	176.4	175.1	158.0
	SEM±		0.76	1.28	0.75	1.07	1.18	0.94	61.77	61.31	55.40
	CV (%)		3.85	6.48	3.81	8.52	8.73	7.42	3.04	2.97	2.71

Figures in the parentheses are angular transformed values

Table 2. Efficacy of fungicides and insecticides as tank mix against leaf blast of rice during *rabi*, 2012-13 and 2013-14

S. No.	Treatments	Dosage (g or mL/L)	Per cent Disease Index of rice blast					
			Before spray			10 DAS		
			2012	2013	Pooled	2012	2013	Pooled
T_1	Flubendiamide 480 SC	0.1	10.6 (19.02)	10.3 (18.67)	10.5 (18.86)	33.7 (35.48)	37.4 (37.68)	35.6 (36.59)
T_2	Chlorantraniliprole 20 SC	0.3	10.6 (19.02)	10.6 (19.02)	10.6 (19.05)	33.7 (35.48)	35.9 (36.81)	34.8 (36.15)
T_3	Cartap hydrochloride 50 SP	2.0	10.3 (18.67)	10.6 (19.02)	10.5 (18.86)	33.0 (35.03)	37.4 (37.68)	35.2 (36.37)
T_4	Buprofezin 25 SC	2.0	10.3 (18.67)	10.3 (18.67)	10.3 (18.67)	33.0 (35.04)	36.7 (37.24)	34.8 (36.15)
T_5	Profenophos 50 EC	2.0	10.3 (18.67)	10.3 (18.67)	10.3 (18.67)	34.5 (35.91)	37.4 (37.69)	35.9 (36.81)
T_6	Tricyclazole 75 WP	0.6	11.0 (19.36)	10.6 (19.02)	10.8 (19.21)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_7	Hexaconazole 5 EC	2.0	10.3 (18.67)	10.3 (18.67)	10.3 (18.71)	31.5 (34.15)	31.5 (34.15)	31.5 (34.15)
T_8	Propiconazole 25 EC	1.0	9.9 (18.31)	11.0 (19.36)	10.5 (18.86)	30.8 (33.69)	33.0 (35.05)	31.9 (34.37)
T_9	Flubendiamide + Tricyclazole	0.1 + 0.6	9.9 (18.33)	10.3 (18.67)	10.1 (18.52)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_{10}	Flubendiamide + Hexaconazole	0.1 + 2.0	10.3 (18.67)	10.3 (18.67)	10.3 (18.71)	31.5 (34.15)	31.5 (34.15)	31.5 (34.15)
T_{11}	Flubendiamide + Propiconazole	0.1 + 1.0	10.6 (19.02)	10.3 (18.67)	10.5 (18.86)	32.3 (34.59)	31.5 (34.15)	31.9 (34.37)
T_{12}	Chlorantraniliprole + Tricyclazole	0.3 + 0.6	9.2 (17.61)	9.9 (18.33)	9.5 (18.01)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_{13}	Chlorantraniliprole + Hexaconazole	0.3 + 2.0	10.6 (19.02)	9.9 (18.33)	10.3 (18.71)	32.3 (34.60)	30.8 (33.70)	31.5 (34.15)
T_{14}	Chlorantraniliprole + Propiconazole	0.3 + 1.0	10.3 (18.66)	10.3 (18.67)	10.3 (18.70)	31.5 (34.14)	31.5 (34.15)	31.5 (34.14)
T_{15}	Cartap hydrochloride + Tricyclazole	2.0 + 0.6	10.6 (19.02)	10.3 (18.67)	10.5 (18.86)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_{16}	Cartap hydrochloride + Hexaconazole	2.0 + 2.0	10.6 (19.02)	10.6 (19.02)	10.6 (19.02)	33.7 (35.49)	32.3 (34.60)	33.0 (35.05)
T_{17}	Cartap hydrochloride + Propiconazole	2.0 + 1.0	11.0 (19.36)	10.3 (18.67)	10.6 (19.05)	33.0 (35.05)	31.5 (34.15)	32.3 (34.60)
T_{18}	Buprofezin + Tricyclazole	2.0 + 0.6	10.3 (18.66)	10.3 (18.67)	10.3 (18.70)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_{19}	Buprofezin + Hexaconazole	2.0 + 2.0	10.6 (19.02)	10.3 (18.67)	10.5 (18.86)	32.3 (34.60)	31.5 (34.15)	31.9 (34.37)
T_{20}	Buprofezin + Propiconazole	2.0 + 1.0	9.5 (17.87)	9.9 (18.31)	9.7 (18.12)	30.8 (33.67)	30.8 (33.69)	30.8 (33.68)
T_{21}	Profenophos + Tricyclazole	2.0 + 0.6	9.9 (18.31)	10.6 (19.02)	10.3 (18.67)	11.0 (19.36)	11.0 (19.36)	11.0 (19.36)
T_{22}	Profenophos + Hexaconazole	2.0 + 2.0	11.0 (19.36)	10.6 (19.02)	10.8 (19.21)	33.0 (35.05)	32.3 (34.60)	32.6 (34.82)
T_{23}	Profenophos + Propiconazole	2.0 + 1.0	11.0 (19.36)	10.3 (18.67)	10.6 (19.05)	33.0 (35.05)	31.5 (34.15)	32.3 (34.60)
T_{24}	Untreated control	--	10.3 (18.67)	10.3 (18.67)	10.3 (18.65)	38.5 (38.33)	38.9 (38.55)	38.7 (38.45)
	CD		NS	NS	NS	1.90	1.35	1.29
	SEM±		0.42	0.34	0.31	0.67	0.47	0.45
	CV (%)		3.89	3.10	2.88	3.71	2.61	2.51

Figures in the parentheses are angular transformed values due to leaf folder were lowest at 7 DAS and significantly effective treatments were flubendiamide (1.01), chlorantraniliprole (1.01), flubendiamide + tricyclazole (1.02), flubendiamide + hexaconazole (1.01), flubendiamide + propiconazole (1.09), chlorantraniliprole +tricyclazole (1.04), chlorantraniliprole + hexaconazole (0.99) and chlorantraniliprole + propiconazole (1.0) which were followed by cartap hydrochloride (9.45), cartap hydrochloride + tricyclazole (11.36), cartap hydrochloride + hexaconazole (10.99), cartap hydrochloride + propiconazole (11.33) which were on par . The lowest per cent infested leaves were in untreated check (37.63), buprofezin (39.70), tricyclazole (37.30), propiconazole (37.73), buprofezin + tricyclazole (37.48), buprofezin + hexaconazole (37.57), buprofezin + propiconazole (38.39) which were on par.

The overall efficacy of insecticide and fungicide combinations indicated that the insecticides flubendiamide, chlorantraniliprole are highly compatible with all fungicides by recording lowest per cent infested leaves. These insecticides were followed by cartap hydrochloride and its combinations with fungicides (Table 1).

During *Rabi* 2013-14, almost similar results were obtained as that of *Rabi* 2012-13. At 7 DAS the mean per cent infested leaves were least in the treatments, flubendiamide (1.03), chlorantraniliprole (1.09), flubendiamide + tricyclazole (1.18), flubendiamide + hexaconazole (0.98), flubendiamide + propiconazole (1.05), chlorantraniliprole + tricyclazole (1.01), chlorantraniliprole + hexaconazole (1.09), chlorantraniliprole + propiconazole (0.91) which were on par. These treatments were closely followed by cartap hydrochloride (11.42), cartap hydrochloride + tricyclazole (11.10), cartap hydrochloride + hexaconazole (10.07), cartap hydrochloride + propiconazole (10.14). The highest per cent infested leaves was observed in buprofezin (39.15), tricyclazole (39.43), hexaconazole (38.84), propiconazole (39.23), buprofezin + hexaconazole (40.20), buprofezin + propiconazole (40.19) and untreated check (38.32).

The pooled data of two seasons clearly brought out flubendiamide and chlorantraniliprole and their combinations with tricyclazole, propiconazole, hexaconazole, recorded significantly low leaf folder infested leaves. Prajapathi *et.al.,* (2005) also reported that the damage caused by insect pests specifically leaf folder was significantly lower following application of cartap hydrochloride alone as well as in combination with fungicides hexaconazole and propiconazole compared to untreated control. The present study results also corroborate the findings of Prajapathi *et.al.,* (2005) wherein cartap hydrochloride was found effective both as individual treatment and combination treatments with fungicides. Similarly Bhuvaneswari and Krishnam Raju (2013) also reported that chlorantraniliprole @ 0.3 mL L^{-1} in combination with hexaconazole was effective against stem borer and leaf folder in paddy.

With regard to the leaf blast the mean per cent disease index before treatmental application ranged from 9.2-11.0. The mean PDI of leaf blast after 10 DAS during *rabi,* 2012-13 indicated that there were significant differences among the treatments. The lowest PDI of 11.0 in case of leaf blast was observed in the treatments tricyclazole, flubendiamide + tricyclazole, chlorantraniliprole + tricyclazole, buprofezin + tricyclazole and profenophos + tricyclazole. Similarly during *rabi* 2013-14, the results followed the same trend with tricyclazole alone and their combinations proving best with lowest PDI. Even the pooled data of the two seasons clearly revealed that the treatments tricyclazole alone and tricyclazole with other insecticidal combinations were with lowest incidence of leaf blast. All the treatments which effectively control pest and disease have recorded significantly higher grain yield as compared to the check (Table 2).

CONCLUSION

The effectiveness of the five insecticides and three fungicides did not in any way was hindered.

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EXPRESSION OF HETEROSIS IN INTERVARIETAL CROSSES OF SESAME (*Sesamum indicum* L.)

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ABSTRACT

An experiment was conducted to study the expression of heterosis for ten characters in forty five crosses of sesame developed by crossing five lines with nine testers in Line x Tester mating design. The analysis of variance revealed significant differences among the genotypes for all the characters studied except for number of secondary branches. Heterosis was worked out over midparent, better parent and standard parents *viz.,* CO 1 and TMV 7. For days to fifty per cent flowering and days to maturity, none of the crosses exhibited significant relative heterosis and heterobeltiosis. The cross TMV 5 × ORM 7 expressed significant and positive heterosis over mid-parent, better parent and two standard parents for single plant yield along with high *per se* performance. The crosses TMV 5 × ORM 7, TMV 6 × VRI 1 and TMV 3 × CO 1 expressed highly significant standard heterosis for most of the traits studied including single plant yield and hence could be exploited for developing superior hybrids and varieties.

KEYWORDS: Heterobeltiosis, Relative heterosis, Sesame, Standard heterosis, Yield.

Sesame (*Sesamum indicum* L.) (2n=26), the most ancient oilseed crop of the world, mainly cultivated in tropical and subtropical conditions. It is regarded as the 'Queen of Oilseeds' as the quality of oil is of high nutritional and therapeutic value combined with stability. Sesame is the sixth most important oilseed crop of the world, occupying an area of 9.4 m.ha, with a production of 4.5 m.tons and its average productivity being 515 kg ha^{-1}. India is the largest sesame growing country in the world with an area of 1.86 m.ha, producing 0.64 m. tons but productivity wise, it is among the lowest with 345 kg ha^{-1} (FAOSTAT, 2013), much lower than the world average productivity. This can be overcome by the commercial exploitation of heterosis.

Since this crop has epipetatious flower nature, easy emasculation and pollination procedure, pollen transfer by honey bee activity, more number of seedset in a capsule, more number of capsules per plant, low seed rate (5.0 kg ha^{-1}) and high multiplication ratio, it has more scope for manual hybrid seed production to exploit heterosis. Also, several researchers already reported the presence of significantly high heterosis for yield and yield components, like Anandakumar (1995), Saravanan and Nadarajan (2002), Mothilal and Ganesan (2005), Anuratha and Lakshmi Kantha Reddy (2008). Hence the present investigation was carried out to study the magnitude of heterosis for yield and yield components to exploit in our breeding programme.

MATERIALS AND METHODS

The material for the present study consisted of five female parents, *viz.,* TMV 3, TMV 4, TMV 5, TMV 6, Paiyur 1 and nine males *viz.,* CO 1, SVPR 1, TMV 7, VRI 1, VRI 2, Jaumer, ORM 7, ORM 14 and ORM 17. Crosses were made in Line × Tester mating design to develop 45 hybrids at the Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore during Rabi-Summer 2012-13. Individual cross combinations along with their parents were raised in Randomized Block Design along with two checks *viz.,* TMV 7 and CO 1 in two replications, each in two rows of four meter length with the spacing of 30 × 30 cm, during *Kharif*, 2013. The recommended package of practices for sesame was followed throughout the crop growing period. Observations were recorded for ten traits *viz.,* days to first flowering, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of capsules in main stem, total number of capsules per plant, number of seeds per capsule, single plant yield (g) and 100 seed weight (mg). Ten plants in parents and

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hybrids were randomly selected in each replication and observations on the quantitative traits were recorded. The mean values were used for estimation of heterosis over mid parent, better parent and standard check as per the standard method.

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among parents for the ten quantitative characters studied (Table 1). This indicates the presence of significant variation in the experimental material for the traits observed. Significant variation was also observed among hybrids for all the characters observed in this study except for days to maturity, indicating the variability among the crosses for the other observed traits. The interaction among the crosses and parents recorded significant variation for all the observed traits except for number of secondary branches per plant indicating the possibility of exploiting heterosis for most of the traits. Similar results were also observed by Kar *et al.* (2002), Thiyagu *et al.* (2007), Jadhav and Mohir (2013) for most of the characters studied in this experiment.

Heterosis for single plant yield ranged from -69.57 to124.18, from -71.54 to 104.13 per cent over mid parent and better parent respectively and from -68.75 to 98.66 and from -74.12 to 64.51 per cent over standard varieties i.e., TMV 7 and CO 1, respectively. The cross TMV 5 × ORM 7 expressed significant and positive heterosis over mid parent, better parent and two standard varieties with the mean seed yield of 44.5 g plant^{-1}. The crosses TMV 3 × CO 1, TMV 5 × ORM 14 and TMV 6 × VRI 1 recorded significant and positive relative heterosis, heterobeltiosis and standard heterosis over CO 1 alone for seed yield per plant. Among forty five crosses studied, significant and positive relative heterosis was observed in eleven crosses, heterobeltiosis in nine crosses, standard heterosis in one cross (TMV 5 × ORM 7) over the standard variety TMV 7 and four crosses over the standard variety CO 1 for seed yield per plant. Minimum number of crosses exhibiting standard heterosis as compared to relative heterosis and heterobeltiosis was already observed by Jayaprakash and Sivasubramanian (2000); Mothilal and Manoharan (2004), Padmasundari and Kamala (2012) and Jawahar lal Jatothu *et al.* (2013).

The number of crosses with significant heterotic performance and range of heterosis for yield and yield components are given in Table 2 and the crosses are given in Table 3. For earliness, none of the crosses exhibited significant relative heterosis and heterobeltiosis, while the crosses TMV 4 × Jaumer, TMV 5 × ORM 7 and Paiyur 1 × ORM 17 showed significant and negative standard heterosis over CO 1. For days to maturity, TMV 6 × ORM 17, TMV 3 × SVPR 1 and TMV 6 × SVPR 1 showed significant and negative standard heterosis over CO 1. For plant height, TMV 3 × CO 1 expressed significant and positive heterosis over midparent, better parent and over two standard varieties used. Significant positive heterosis for plant height was reported by Ananda Kumar (1995), Navadiya *et al.* (1995), Mishra and Sikarwar (2001), Mothilal and Ganesan (2005) and Parimala *et al.* (2013). For number of primary and secondary branches, TMV 6 × VRI 1 showed significant and positive relative heterosis and heterobeltiosis. TMV 3 × CO 1 expressed significant values of standard heterosis over TMV 3 × CO 1 for number of secondary branches.

For the number of capsules in main stem, Paiyur 1 × ORM 7 and Paiyur 1 × ORM 14 had the significant and positive heterosis over mid and better parent, while TMV 5 × ORM 7, TMV 3 × ORM 7 and TMV 5 Jaumer was significantly heterotic over the standard varieties CO 1 and TMV 7. The cross Paiyur 1 × ORM 7 recorded significant and positive relative heterosis, heterobeltiosis and standard heterosis for total number of capsules per plant. For number of seeds per capsule, Paiyur 1 × ORM 7 and TMV 3 × VRI 1 expressed significant and positive heterotic values on all the three bases. Significant heterosis for number of seeds per capsule was also reported by Mishra and Yadav (1996), Mishra and Sikarwar (2001), Mothilal and Ganesan (2005) and Parimala *et al.* (2013). For single plant yield, TMV 5 × ORM 7, Paiyur 1 × SVPR 1 expressed significant and high relative heterosis and heterobeltiosis, while TMV 5 × ORM 7 showed significant and positive heterosis on all the three bases. Similar results were also reported by Padmavathi (1998), Deepa Sankar and Ananda Kumar (2001), Saravanan and Nadarajan (2002) and Thiyagu *et al.* (2007). For 100 seed weight, Paiyur 1 × VRI 1, TMV 3 × Jaumer and TMV 5 × VRI exhibited positive and highly significant heterosis on all the three bases.

The crosses showing standard heterosis for single plant yield and other contributing traits are given in Table 4. The hybrid TMV 5 × ORM 7 expressed high heterosis for single plant yield, number of capsules in main stem, total number of capsules per plant, while the cross TMV

Table 1. Analysis of variance for ten quantitative traits in sesame

Source of variation	Replication	Crosses	Parents	Crosses vs Parents	Error
d.f	1	44	13	1	58
Days to first flowering	6.46	10.6**	21.06**	1008.12**	1.71
Days to maturity	4.33	4.24	147.64**	453.61**	2.99
Plant height	41.05	251.96**	579.96**	2110.58*	49.56
No. of primary branches	0.26	0.82**	2.59**	2.64**	0.3
No. of secondary branches	0.22	1.19**	1.66**	14.4	0.52
No. of capsules in main stem	4.37	54.22**	29.77**	366.66**	9.44
Total no. of capsules	0.2	847.97**	681.87**	4854.28**	25.35
No. of seeds /capsule	0.19	23.71**	20.31**	133.53**	5.35
Single Plant Yield	3.29	101.39**	19.20*	18.76*	7.86
100 Seed Weight	4.1	941.58**	166.92**	2327.27**	15.27

6 × VRI 1 showed heterotic vigour for three traits viz., single plant yield, number of secondary branches, 100 seed weight. The hybrid TMV 3 × CO 1 was superior for single plant yield, plant height and number of secondary branches. For number of primary branches, number of capsules in main stem and number of seeds per capsule, the cross TMV 3 × VRI 1 was identified as highly heterotic over standard parents. The cross TMV 5 × Jaumer expressed high heterosis for three traits viz., plant height, total number of capsules per plant and number of capsules in main stem. For number of primary branches and total number of capsules per plant, the hybrid Paiyur 1 × ORM 14 had expressed high heterosis. These highly heterotic crosses can be utilized for yield improvement through heterosis breeding.

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Table 2. Number of crosses with desirable heterotic performance for yield and yield components

Particulars	Days to 50% flowering	Days to maturity	Plant height	No. of 1 branches	No. of 2 branches	No. of capsules in main stem	Total no. of capsules	No. of seeds / caps	100 seed weight	Single plant yield
With desirable relative heterosis	0	6	3	11	10	20	26	15	18	11
With desirable heterobeltiosis	0	13	1	6	5	10	11	9	7	9
With desirable standard heterosis over TMV 7	2	0	8	21	16	11	13	6	7	1
With desirable standard heterosis over CO 1	16	11	1	0	10	15	7	4	9	4
Range of relative heterosis (%)	-19.61 to 38.81	-5.44 to 14.51	-25.26 to 34.58	-33.86 to 59.46	-37.78 to 142.62	-33.62 to 74.92	-35.62 to 147.60	-5.70 to 18.0	-4.41 to 25.02	-69.57 to 124.18
Range of hetero-beltiosis(%)	-15.82 to 30.32	-6.09 to 6.44	-29.85 to 23.11	-36.36 to 36.36	-50.05 to 114.63	-36.89 to 48.09	-39.84 to 65.71	-9.87 to 14.71	-6.15 to 24.12	-71.54 to 104.13
Range of standard heterosis (%) over TMV 7	-2.33 to 17.42	3.158 to 31.58	-2.07 to 67.73	-12.19 to 51.22	-34.88 to 118.61	-37.14 to 52.25	-25.45 to 85.48	-5.74 to 17.83	-1.96 to 27.45	-68.75 to 98.66
Range of standard heterosis (%) over CO 1	-17.00 to 1.00	-11.71 to 12.61	-27.43 to 24.29	-56.52 to 10.42	-57.58 to 42.42	-43.49 to 36.88	-40.26 to 48.64	-9.30 to 13.37	-8.40 to 19.08	-74.12 to 64.51

Table 3. Best three crosses showing high heterotic vigour for yield and yield components

Character	Relative heterosis	Heterobeltiosis	Standard heterosis	
			TMV 7	CO 1
Days to flowering	--	--	TMV 4 × Jaumer	TMV 4 × Jaumer
			TMV 5 × ORM 7	TMV 5 × ORM 7
			--	Paiyur 1 × ORM 17
Days to maturity	--	--	--	TMV 6 × ORM 17
				TMV 3 × SVPR 1
				TMV 6 × SVPR 1
Plant height (cm)	TMV 3 × CO 1	TMV 3 × CO 1	TMV 3 × CO 1	TMV 3 × CO 1
	Paiyur 1 × SVPR 1	--	TMV 5 × Jaumer	--
	TMV 3 × SVPR 1	--	Paiyur 1 × CO 1	--
No. of 1 branches	TMV 6 × VRI 1	TMV 5 × ORM 14	Paiyur 1 × ORM 14	--
	TMV 5 × VRI 1	TMV 6 × VRI 1	TMV 3 × VRI 1	
	TMV 4 × SVPR 1	TMV 5 × VRI 1	TMV 5 × ORM 14	
No. of 2 branches	TMV 6 × Jaumer	TMV 6 × VRI 1	TMV 5 × VRI 2	TMV 5 × VRI 2
	TMV 6 × VRI 1	TMV 6 × Jaumer	TMV 3 × CO 1	TMV 3 × CO 1
	TMV 5 × SVPR 1	TMV 6 × ORM 7	TMV 6 × VRI 1	TMV 6 × VRI 1
No. of capsules in main stem	Paiyur 1 × SVPR 1	Paiyur 1 × ORM 7	TMV 5 × ORM 7	TMV 5 × ORM 7
	Paiyur 1 × ORM 7	Paiyur 1 × Jaumer	TMV 3 × ORM 7	TMV 3 × ORM 7
	Paiyur 1 × ORM 14	Paiyur 1 × ORM 14	TMV 5 × Jaumer	TMV 5 × Jaumer
Total no. of capsules/plt	Paiyur 1 × SVPR 1	Paiyur 1 × ORM 7	Paiyur 1 × ORM 7	Paiyur 1 × ORM 7
	Paiyur 1 × ORM 7	Paiyur 1 × ORM 14	Paiyur 1 × ORM 14	Paiyur 1 × ORM 14
	TMV 5 × Jaumer	TMV 3 × ORM 17	TMV 5 × Jaumer	TMV 5 × Jaumer
No. of seeds/capsule	Paiyur 1 × ORM 7	TMV 3 × VRI 1	Paiyur 1 × ORM 7	Paiyur 1 × ORM 7
	TMV 3 × VRI 1	Paiyur 1 × ORM 7	TMV 3 × VRI 1	TMV 3 × VRI 2
	TMV 3 × ORM 17	TMV 3 × ORM 17	TMV 3 × TMV 7	TMV 3 × VRI 1
Single plant yield	TMV 5 × ORM 7	TMV 5 × ORM 7	TMV 5 × ORM 7	TMV 5 × ORM 7
	Paiyur 1 × SVPR 1	Paiyur 1 × ORM 7	TMV 3 × CO 1	TMV 3 × CO 1
	Paiyur 1 × ORM 7	TMV 6 × VRI 1	TMV 6 × VRI 1	TMV 6 × VRI 1
100 seed weight	Paiyur 1 × VRI 1	Paiyur 1 × VRI 1	Paiyur 1 × VRI 1	Paiyur 1 × VRI 1
	TMV 3 × Jaumer	TMV 3 × Jaumer	TMV 3 × Jaumer	TMV 3 × Jaumer
	TMV 3 × VRI 1	TMV 3 × VRI 1	--	--

Table 4. List of hybrids showing standard heterosis for seed yield per plant and other traits

Cross	Characters
TMV 5 × ORM 7	Single plant yield, Number of capsules in main stem and Total number of capsules per plant
TMV 3 × CO 1	Single plant yield, Plant height and Number of 2 branches
TMV 6 × VRI 1	Single plant yield, Number of 2 branches and 100 seed weight
TMV 3 × VRI 1	Number of 1 branches, Number of seeds per capsule and Number of capsules in main stem
TMV 5 × Jaumer	Plant height, Total number of capsules per plant and Number of capsules in main stem
Paiyur 1 × ORM 14	Number of 1 branches and Total number of capsules per plant

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EVALUATION OF BIOINTENSIVE PEST MANAGEMENT MODULE AGAINST INSECT PEST COMPLEX OF RICE

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ABSTRACT

Experiments were conducted at Krishi Vigyan Kendra farm, Undi and its adopted villages *viz.* Matsyapuri, Adavikolanu, Mogallu, Kakaraparru and Guttulavaripalem, West Godavari district, Andhra Pradesh in the farmer's field during *kharif* and *rabi* seasons of 2008-09, 2009-10 and 2010-11 to assess the performance of Bio Intensive Pest Management (BIPM) module against major insect pests of rice (var. Swarna) in comparison to the farmers practice of recommended insecticidal control schedule (non-BIPM module). Analysis of three year results showed that BIPM treated plots recorded significantly lesser dead hearts (1.4 to 6.4 %), white ears (2.1 to 8.0 %) and leaf folder damage (2.6 to 8.2%) compared to the plots grown using farmers' practices. Similarly significantly lower incidence of brown plant hopper (4.6 to 9.6 / 10 hills), white backed plant hopper (2.8 to 11.7 / 10 hills) and green leaf hopper (2.8 to 9.3 / 10 hills) was noticed in BIPM plots as compared to non-BIPM plots (10.2 to 21.1 BPH / 10 hills, 5.4 to 17.1 WBPH / 10 hills and 6.7 to 15.6 GLH / 10 hills). BIPM plots also recorded significantly higher numbers of predatory population of spiders, coccinellid beetles and mirid bugs. Grain yield in biocontrol field (5996 Kg ha^{-1}) was significantly better as compared to 5626 Kg ha^{-1} in farmer's practice. The average net returns in biocontrol package were ₹ 30312 ha^{-1} as compared to ₹ 22951 ha^{-1} in farmers' practice with cost benefit ratio of 1: 2.04 and 1: 1.71, respectively. Therefore, the BIPM technology used was not only directly environment friendly but also more sustainable with a vide increase in biodiversity.

KEY WORDS: Bio intensive pest management, rice, major insect pests, predators

India has the largest area under rice in the world and ranks second among the rice producers, accounting for above 20 per cent of global rice exports. However, insect pests are responsible for considerable yield losses and about 128 species of insects have been reported to ravage the rice crop. Out of this, only 15 to 20 insects are regarded as economically obnoxious species (Kalode, 2005), the stem borer being the major one, which cause losses up to 90% if not managed timely. Rice is cultivated with selected high-yielding varieties in temporal and spatial continuum, with high inputs of chemical fertilizers and insecticides most often used indiscriminately resulting in several problems including that of residues. With a view to reduce the load of pesticides in environment and to improve socio economic status of farmers, Integrated Pest Management (IPM) practices have been formulated and have been successfully validated in rice in selected districts of the states such as Andhra Pradesh, Tamil Nadu, Kerala, Haryana, Madhya Pradesh and Utter Pradesh. Results have demonstrated that there had been a reduction of pesticide sprays (Razak, 1986). With further refinement and utilization of Bio Intensive Pest Management (BIPM) techniques, *viz.* pheromone traps and bio-agents which are environment friendly, reduce pest pressure and can earn profitable incomes for the farmers certainly seems to be an effective alternative for managing the rice insect pests.

Biointensive IPM incorporates ecological and economic factors into agricultural system design and decision making and addresses public concerns about environmental quality and food safety. Its benefits include reduced chemical input costs, reduced on-farm and off-farm environmental impacts and more effective and sustainable pest management (Dufour, 2001). Pheromone and bioagents are species-specific, have no adverse effect on the non-targets and hence would be fully compatible with other management approaches to control rice insect pests (Katti *et al.*, 2001; Garg *et al.*, 2002; Kaur *et al.*, 2003; Ignacimuthu, 2005; Mahal *et al.*, 2006). Hence, the present study was undertaken to evaluate BIPM practices in rice in comparison to the recommended insecticidal control schedule against major insect pests of rice.

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MATERIALS AND METHODS

In order to validate rice BIPM module to suppress major insect pests at regional level, on farm testing of BIPM practices in rice was carried out with widely cultivated paddy variety *Swarna* (MTU 7029) during three consecutive *kharif* and *rabi* cropping seasons of 2008-09, 2009-10 and 2010-11 at Krishi Vigyan Kendra farm, Undi and its adopted villages *viz.* Matsyapuri, Adavikolanu, Mogallu, Kakaraparru and Guttulavaripalem of West Godavari district, Andhra Pradesh in the farmer‘s field covering an area of 6 ha each year. On farm trials (OFTs) were taken up each in one hectare block divided equally into two identical plots, one half receiving the BIPM technology and other half with farmers practice of recommended insecticidal control schedule. Paddy in each plot was grown separately under the supervision of single management schedule. Seedlings were raised in the nursery for both the plots at the rate of 25 kg seed for 5 cents seed bed during 29 and 49 standard meteorological weeks (SMW) respectively for *kharif* and *rabi* seasons. Main field experiment was conducted with 25-30 day old transplanted seedlings. Transplantation with 2 seedlings / hill was done during 33 and 52 SMW respectively for *kharif* and *rabi* seasons in pre-puddled field.

Efficacy of rice-BIPM module advocated by the All India Coordinated Research Project on Biological Control, A.R.I. Campus, Rajendranagar, Hyderabad to suppress major insect pests was taken as working-standard after befitting modifications and it was compared with the module of farmer’s conventional practices. So, there were two treatment schedules (i) BIPM schedule and (ii) non-BIPM schedule i.e conventionally cultivated farmers’ practice (FP) of recommended insecticidal control schedule. Treatment particulars for both the management practices are delineated below:

The BIPM package comprised of

- Seedling root dip treatment with *Pseudomonus fluorescens* @ 2% solution;
- Erection of bird perches @ 10 ha^{-1} from 15 Days After Transplantation (DAT) up to panicle emergence stage;
- Spray of Botanicals (Neemazal 1500 ppm @ 5 ml lt^{-1}) at 20 DAT and 40 DAT against foliar as well as sucking pests;
- Mass trapping of male yellow stem borer moths with pheromone traps @ 20-25 ha^{-1} from 25 DAT
- Six releases of *T. japonicum* @ 1,00,000 ha^{-1} at ten days interval starting from 30 DAT against *Scirpophaga* spp.,
- Spray of *Bacillus thuriengenisis* formulation (Halt 5% WP) against caterpillar pests @ 2 Kg ha^{-1} at 30 DAT
- Two sprays of *Beauveria bassiana* @ 10^{13} spores ha^{-1} at 40 DAT and 70 DAT against sucking pests;
- Spray of *P. fluorescens* 10 g lt^{-1} at 45 DAT and 60 DAT against foliar diseases;

FP package

- Seed treated with carbendazim 50% WDP @ 3.0 g kg^{-1} seed;
- Spraying of chlorpyriphos 20 EC @ 2 ml lt^{-1} at 25 DAT against gall midge and hispa;
- Application of Carbofuran 3G granules in the nursery 1 week before pulling and again at 35 DAT;
- Spraying Cartap hydrochloride @ 2 g lt^{-1} at 45 DAT and 60 DAT against stem borer and leaf folder;
- Spraying of Profenophos @ 2 ml lt^{-1} at PI stage and again 15 days after panicle emergence against panicle mite;
- Foliar application of Buprofezin 25 SC@ 1.5 ml lt^{-1} at 75 and 85 days after transplantation (DAT) against plant and leaf hoppers.

Observations on pest incidence and population of natural enemies were recorded from both BIPM and non BIPM plots. Dead Heart (DH) and White Ears (WE) caused by stem borer during vegetative and panicle emergence stage; leaf scraping caused by leaf folder was assessed from 50 hills diagonally selected from each plot and is converted as percentage damage (Table 1). Further 10 hills were selected randomly from each plot and from that the numerical abundance of brown plant hopper, white backed plant hopper and green leaf hopper population was noted and the average was worked out. Population of spiders, coccinellid beetles and mirid bugs were recorded from 1 m^2 area and the average was worked out.

Table 1. Mean incidence of major insect pests and natural enemies of rice in BIPM and non BIPM plots during 2008-09, 2009-10 and 2010-11

Insect pests and natural enemies	Dead heart damage (%)		White Ear damage (%)		Rice leaf folder damage (%)		Brown plant hopper (No./10 hills)		White backed plant hopper (No./10 hills)		Green leaf hopper (No./10 hills)		Spiders (No./ sq.m)		Coccinellids (No./ sq.m)		Mirid bug (No./10 hills)	
	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP
Kharif 2008	2.1	2.8	2.1	3.1	4.7	12.7	8.4	21.1	6.9	11.8	6.5	15.4	1.8	0.6	1.7	0.7	19.5	5.4
"t" value	2.3		3.3		8.3		6.4		3.4		4.9		4.6		3.5		7.5	
Remarks	NS		S*		S**		S**		S*		S*		S**		S**		S**	
Rabi 2008-09	2.6	3.5	2.8	3.9	2.6	4.3	9.3	15.1	11.7	17.1	9.3	14.9	2.0	0.7	2.5	0.9	22.2	7.5
"t" value	4.5		5.9		6.5		5.9		2.9		3.1		5.2		6.3		18.5	
Remarks	S**		S**		S**		S**		S*		S*		S**		S**		S**	
Kharif 2009	1.8	2.6	6.2	21.9	8.2	13.6	4.6	10.2	2.8	5.4	4.3	8.8	8.2	1.6	3.9	0.9	17.4	4.2
"t" value	2.2		5.0		6.0		4.9		4.6		4.4		10.1		12.4		6.5	
Remarks	NS		S**		S**		S**		S**		S**		S**		S**		S**	
Rabi 2009-10	2.6	6.8	4.7	11.2	5.2	9.3	5.5	13.1	5.2	9.2	2.8	6.7	3.1	0.7	2.6	0.9	39.2	3.8
"t" value	41.6		9.6		5.4		5.9		5.0		5.8		7.1		6.3		10.7	
Remarks	S**		S**		S**		S**		NS		S**		S**		S**		S**	
Kharif 2010	1.4	3.4	3.0	10.6	3.2	6.3	9.6	19.7	6.7	11.8	6.6	15.6	4.5	1.6	3.9	1.3	27.6	14.7
"t" value	13.0		13.9		9.4		4.5		4.3		6.2		9.4		9.4		8.8	
Remarks	S**		S**		S**		S**		S**		S**		S**		S**		S**	
Rabi 2010-11	6.4	13.7	8.0	22.3	4.8	8.1	5.1	12.6	4.8	9.2	6.6	9.8	3.2	1.2	1.8	0.6	15.2	3.5
"t" value	7.6		11.1		4.2		15.8		4.8		3.1		7.1		7.4		13.5	
Remarks	S**		S**		S**		S**		S**		S*		S**		S**		S**	

S* : Mean values differ significantly at 5% by "t" test
S** : Mean values differ significantly at 1% by "t" test

Table 2. Mean grain yield and economics of rice in BIPM and non BIPM plots during 2008-09, 2009-10 and 2010-11

Particulars	Grain Yield (Kg/ha)		% increase in yield		Cost of cultivation (₹/ha)		Gross income (₹/ha)		Net returns (₹/ha)		B : C ratio	
	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP	BIPM	FP
Kharif 2008	6063.4	5929.4	2.2	-	24775	29400	52775	51524	28000	22124	1:2.13	1:1.75
"t" value	3.38											
Remarks	S*											
Rabi 2008-09	6226.0	6084.0	2.3	-	28678	33478	58524	57190	29846	23712	1:2.04	1:1.71
"t" value	5.48											
Remarks	S**											
Kharif 2009	6084.0	5580.0	9.0	-	30035	32750	61655	56544	31620	23794	1:2.05	1:1.73
"t" value	2.8											
Remarks	S*											
Rabi 2009-10	6384.0	6007.1	6.3	-	30825	34125	66394	62474	35569	28349	1:2.15	1:1.83
"t" value	2.9											
Remarks	S*											
Kharif 2010	4750.0	4375.0	8.6	-	28373	31063	48767	44917	20394	13854	1:1.72	1:1.45
"t" value	2.4											
Remarks	S*											
Rabi 2010-11	6468.8	5781.3	11.9	-	31130	34250	67575	60125	36445	25875	1:2.16	1:1.76
"t" value	8.2											
Remarks	S**											
Mean	5996.1	5626.1	6.6		28969	32511	59282	55462	30312	22951	1:2.04	1:1.71

S* : Mean values differ significantly at 5% by "t" test
S** : Mean values differ significantly at 1% by "t" test

Finally economics of both the treatment schedules under consideration was worked out depending on the final grain yield, existing market price of the produce and detail cost of field management (Table 2). The values of cost benefit ratio thus obtained are tabulated. Data on pest incidence, natural enemies and grain yield in BIPM and non-BIPM plots were analyzed statistically following student 't' test and relative superiority of the module was determined.

RESULTS AND DISCUSSION

Incidence of major insect pests of rice

Considering of DH (%) non-significant difference between the BIPM and non-BIPM plots was noted during *kharif*, 2008 and *kharif*, 2009 (Table 1). But for the subsequent years the differences were significant for both DH (%) and WH (%). The extent of damage was 1.4 to 6.4 % for DH and 2.1 to 8.0 % for WH in BIPM plots. While the corresponding values were 2.8 to 13.7% for DH and 3.1 to 22.3% for WH in non-BIPM plots. Data on rice leaf folder damage (%) exemplified that the BIPM plots during the experimental years exhibited significantly low (2.6 to 8.2%) damage over the non-BIPM plots (4.3 to 13.6%). Similarly, significantly lower incidence of brown plant hopper (4.6 to 9.6 / 10 hills), white backed plant hopper (2.8 to 11.7 / 10 hills) and green leaf hopper (2.8 to 9.3 / 10 hills) was noticed in BIPM plots as compared to non-BIPM plots (10.2 to 21.1 BPH / 10 hills, 5.4 to 17.1 WBPH / 10 hills and 6.7 to 15.6 GLH / 10 hills). Present findings on lower pest population in BIPM plots are in conformity with those of Anitha and Parimala (2014).

Occurrence of natural enemies

Numerical abundance of spider and coccinellid beetle population in BIPM plots was 1.8 to 8.2 and 1.7 to 3.9 individuals sq.m^{-1}, respectively. The corresponding value in non-BIPM field was 0.6 to 1.6 for spider and 0.6 to 1.3 for beetle population. BIPM module influenced the abundance of both spider and beetle number significantly in all the experiment years in comparison to non-BIPM plots. The important predatory spiders recorded were *Oxyopes javanus*, *Clubiona*, *Tetragnattha* sp. and *Lycosa pseudoannulata.* In case of coccinellids beetles, *Micraspis* sp. was more predominant up to panicle initiation stage of the crop. BIPM plots also recorded significantly higher numbers of mirid bugs (15.2 to 39.2 / 10 hills) over non-BIPM plots (3.5 to 14.7 / 10 hills). Thus the location specific BIPM package resulted in increased biodiversity as this is safer to natural enemies of rice pests thus enhancing chances of natural control. Lower population of predators in non-BIPM module was due to the toxic effect of the insecticides. The present work highlights the importance of following eco-friendly pest management practices to safeguard the diversity of natural enemies in the rice crop ecosystem.

Grain yield and economics

Significant impact of BIPM module over non-BIPM module was also reflected on grain yield (Table 2). The BIPM plots recorded higher grain yield (4750 to 6469 kg ha^{-1}) as compared to non-BIPM plots (4375 to 6084 kg ha^{-1}) during all cropping seasons. The mean value of grain production was 5996 kg ha^{-1} for BIPM and 5626 kg ha^{-1} non-BIPM field. BIPM plots showed an overall increase of 6.6 per cent grain yield over non-BIPM plots. Suneel Kumar *et al.* (2007) and Anitha and Parimala (2014) also reported that maximum grain yield was obtained from plots cultivated with BIPM practices compared to other package of IPM or farmers practice. BIPM plots were economically superior to non-BIPM plots. Average net returns under BIPM plots (₹ 30312 ha^{-1}) was relatively higher than non-BIPM plots (₹ 22951 ha^{-1}). Further the mean input expenditure in BIPM plots (₹ 28969 ha^{-1}) was comparatively lower than non-BIPM plots (₹ 32511 ha^{-1}). Ultimately the Cost Benefit Ratio (CBR) in BIPM plot (1:2.04) was superior than the non-BIPM plots (1:1.71). Ramandeep Kaur *et al.* (2007) also reported that adoption of BIPM technology in Basmati rice gave higher CBR.

CONCLUSION

It can be concluded that BIPM package proved effective over farmers practice on large scale for the management of important key pests of rice. Thus cultivation of rice by BIPM module is found to be economically prudent to suppress key insect pest incidence and accordingly to boost up the production besides maintaining ecological balance.

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FEASIBILITY OF DIFFERENT CROP ESTABLISHMENT TECHNIQUES FOR UPLAND RICE IN KRISHNA DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Different rice establishment techniques were tested against traditional method of transplanting for feasibility in upland rice farming situation in Krishna district during *rabi*, 2012-13. The techniques comprised direct seeding through broadcasting, sowing of sprouted seed using drum seeder, System of Rice Intensification and System of Rice Intensification under mechanization (MSRI) along with conventional transplanting. Rice variety; MTU 1010 was used in all the trials. Costs involved for each operation were collected and returns per rupee of expenditure were worked out. For crop establishment under drum seeding (₹ 657) and broad casting (₹ 750) methods, the cost involved was very less. Direct sowing through broadcasting realized higher gross return (₹ 98500) and net income (₹ 72475) with higher returns per rupee expenditure (3.78). The study emphasizes the need of alternate methods of rice crop establishment for reducing cost of cultivation in uplands considering the factors such as weather conditions, type of soil, availability of water and labour.

KEYWORDS: Rice, Broadcasting, Drum seeding, System of Rice Intensification.

Rice (*Oryza sativa*), the staple food for most of the Indians occupies a significant position in the agricultural economy of the country. West Godavari, East Godavari and Krishna are three most important rice producing districts of Andhra Pradesh and account for over 7 per cent of the total rice production of the country. The topographical area of Krishna district can be divided into delta area with black heavy soils that receives canal irrigation and upland area with light soils which is dependent on tube wells and tanks for irrigation. Though rice is grown by adopting various crop establishing techniques; transplanting of seedlings is the traditional method followed from many years in Krishna district, which involves various operations. This is a time consuming, labour intensive method which requires more water for land preparation as well as for the establishment of crop. Transplantation is mostly done by contract labour by random planting often with sub optimal plant density per unit area. Availability of farm labour is also drastically reduced, especially for operations like transplanting and weeding. Delayed planting affects crop growth and yields and thereby reduces system productivity and profitability. Owing to these problems, the rice farmers adopting transplantation are inclining towards alternate methods which are economical and environmentally appropriate for rice crop production. Direct seeding can reduce labour needs by more than 20 per cent in terms of working hours required (Santhi *et al*., 1998). The System of Rice Intensification (SRI) has been successfully used in a number of countries. The SRI system saved about 64% of water compared with the conventional paddy system (Mwatete *et al*., 2015). Similarly, the benefits of various cost reduction technologies like machine planting (Venkateswarlu *et al*., 2011) and drum seeding (Manoranjan *et al*., 2011; Sucheta and Hensel., 2012) have been reported.

MATERIALS AND METHODS

Different rice establishment techniques were tested against traditional method of transplanting for feasibility in upland rice farming situation on farmers fields of Krishna district during *rabi* season, 2012-13. The techniques comprised direct seeding through broadcasting (2 locations), sowing of sprouted seeds using drum seeder (2 locations), System of Rice Intensification (4 locations) and System of Rice Intensification under mechanization (MSRI) (4 locations) along with conventional transplanting. Rice variety; MTU 1010 was used in all the trials. In direct sowing, seeds were sown straight in the main field by broadcasting. For wet drum seeding, paddy seeds were soaked in water for 24 hours and incubated for 24-48 hours. These sprouted seeds were sown in puddled field, 1-2 days after puddling using

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Table 1. Yield and yield attributing characters with different establishing techniques in upland rice in Krishna district

Particulars	No. of hills/ m2	No. of tillers/ 5 hills	No. of panicles/ 5 hills	Filled grains(%)/ panicle	Yield (q/ha)
Broadcasting	35.0	30.2	28.6	90.7	78.8
Drum seeder	39.4	24.4	18.3	94.8	49.7
SRI	34.7	27.1	22.4	82.9	63.3
MSRI	30.2	30.1	23.8	91.6	73.6
Transplanting	31.3	24.7	20.7	86.8	59.3

perforated drum seeder. The SRI system involved different practices, while it was slightly modified by involving machine planting as MSRI. Due to delay in onset of monsoons and release of canal water, sowing of paddy crop during *kharif* was delayed with consequent delay in *rabi* sowings. Hence, all the trials were sown only during the month of December, 2012. Yield attributing plant characters such as number of hills/ m^2, number of tillers/ 5 hills, number of panicles/ 5 hills, per cent filled grains/ panicle and yield (q/ha) were recorded. Costs involved for each operation *i.e.,* from land preparation to harvesting in each trial were collected and averaged. Returns per rupee of expenditure in each establishment method were worked out and compared.

RESULTS AND DISCUSSION

There were significant differences in the performance of different crop establishment techniques in terms of yield and yield attributing characters (Table 1); also in terms of economic returns (Figure 1). The cost of field preparation (₹ 9500) was higher for the broadcasting method followed by drum seeding (₹ 7750) as they required fine tilth compared to transplanting and MSRI methods (Table 2). The field preparation cost involved for SRI method of planting was the least (₹ 5156), whereas, for crop establishment (*i.e.,* planting or seeding) both MSRI and SRI methods required higher costs (₹ 12938 and ₹ 11003 respectively) compared to other three methods of planting as these techniques involved skilled/ trained labour. For drum seeding (₹ 657) and broad casting (₹ 750) the cost involved was very less. Fertilizer costs ranged from ₹ 6625 in drum seeding to a maximum of ₹ 8954/- in SRI method.

In transplanting method, the cost involved for crop establishment was ₹ 9416 while the total cost of cultivation was ₹ 36999. The mean yield was 59.3 q/ha which helped to realize a gross return of ₹ 74125 and net income of ₹ 37126 with minimum returns per rupee of expenditure (2.0). In the broadcasted trial plot, yield attributing plant characters such as the number of hills/m^2, no. of tillers and panicles/5 hills, per cent filled grains and yield were higher compared to transplanting. However, the total cost of cultivation (₹ 26025) was low and the yield obtained was higher. Hence, direct sowing through broadcasting realized higher gross return (₹ 98500) and net income (₹ 72475) with higher returns per rupee of expenditure (3.78). During the initial period of crop establishment though weeds became problematic, farmers were able to manage them successfully with the available new herbicides and cultural methods. For weed management, more amount was incurred in transplanting (₹ 4505) while other methods MSRI (₹ 4313), drum seeding (₹ 3850) and SRI (₹ 3713). During *kharif*, broadcasting method though required significantly less cost for establishment, it required significantly higher expenditure towards weed management compared with other methods of establishment (Prasad and Swamy, 2015).

In Drum seeder technique, though, the cost of field preparation (₹ 7750) was little higher, the cost of crop establishment (₹ 657) and the total cost of cultivation (₹ 28232) were low. Hence, direct sowing through drum seeder technique resulted in a gross return of ₹ 62125 and net income of ₹ 33894 with returns per rupee of expenditure (2.20). As the trial plots were surrounded by sugarcane fields, the rice crop was damaged due to rodents. In spite of more amount spent towards rat control, the yields obtained were low. Still direct sowing through

Table 2. Economics of adoption of different crop establishment techniques of rice in upland area of Krishna district

Particulars	Cost of Farm operation (₹/ha)						Total cost of cultivation (₹/ha)	Gross return (₹/ha)	Net income (₹/ha)	Return per rupee of expenditure
	Field preparation	Crop establishment	Fertilizers	Weed management	Plant Protection	Harvesting and threshing				
Broadcasting	9500	750	7150	1750	3125	3750	26025	98500	72475	3.78
Drum seeder	7750	657	6625	3850	4850	4500	28232	62125	33894	2.20
SRI	5156	11003	8954	3713	4219	5000	38045	79125	41081	2.08
MSRI	6188	12938	6750	4313	2669	5000	37857	92000	54144	2.43
Transplanting	5398	9416	7883	4505	4798	5000	36999	74125	37126	2.00

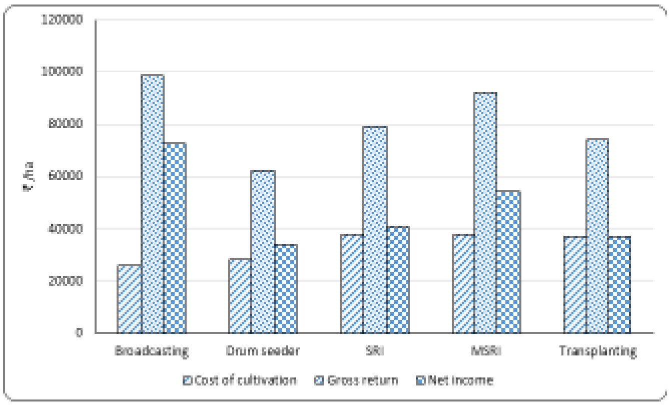

Fig. 1. Performance of different establishing techniques in upland rice

drum seeder realized higher returns per rupee of expenditure compared to transplanting. Similarly, higher yields with low cost of cultivation and higher benefit cost ratios were recorded in drum seeded rice compared to transplanted rice in Vizianagaram (Visalakshi and Sireesha, 2014) and Krishna (Prasad and Swamy, 2015) districts during *kharif* and in Chittoor district (Sreenivasulu and Reddy, 2015) during *rabi*. In SRI plots, as the growth of seedlings in the nursery was not encouraging due to cold weather aged seedlings had to be transplanted. In addition, the crop also suffered from terminal moisture stress which resulted in low yields and realized only a marginal increase in gross return, net income and returns per rupee of expenditure compared to transplanting. The total cost of cultivation (₹ 38045) was little higher as the cost of field preparation (₹ 5156) and crop establishment (₹ 11003) were higher in SRI plot. The findings are in agreement with the observations of Prasad and Swamy, (2015) during *kharif*.

In MSRI system, nursery raising and machine planting was carried through a private firm on contract basis. Though the cost of establishment (₹ 12938) increased the total cost of cultivation (₹ 37857), lesser cost for fertilizers, plant protection and weed management and higher yields increased the gross return (₹ 92000), net income (₹ 54144) and returns per rupee of expenditure (2.43) compared to transplanting. The broadcasting method was also tried in coastal sandy loams; though the number of hills/m^2 and number of tillers/ 5 hills were higher, the number of productive tillers was less compared to conventional method. The reason was that the farmers had taken a crop during *kharif* with long duration variety BPT 5204 in the same field. There were many volunteer plants of BPT 5204 and consumed more inputs, but they did not mature along with the short duration *rabi* variety MTU 1010. This problem was not raised with conventional planting after puddling. As the result, yield as well as gross return, net income and returns per rupee of expenditure were very less in the trial plot compared to transplanting.

Though the costs vary with location, labour demand and management, it is clearly evident from these trials that the alternate methods for rice crop establishment are to be encouraged for reducing cost of cultivation particularly in uplands. However, the choice of a technique should be done based on the type of soil, availability of water and labour duly taking the prevailing weather conditions into account.

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FORECASTING AREA AND PRODUCTION OF WHEAT BY USING UNOBSERVED COMPONENTS MODEL

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ABSTRACT

Forecasting a time series is generally done by using autoregressive integrated moving average (ARIMA) models. The main drawback of ARIMA technique is that the time series should be stationary. In reality, this assumption is rarely met. The Unobserved Component Model (UCM) is a promising alternative to a ARIMA in overlapping this problem as it does not make use of the stationarity assumption. In addition, it breaks down response series into components such as trends, cycles and regression effects, which could be useful especially in forecasting the production of agricultural crops. The present study is aimed at using UCM for annual wheat area and production in India. Results revealed that both the trend components, level and slope were insignificant. The linear trend model zero variance slope was found to be the best fit for the data. The forecast error for the area and production are 2012 and 2013 were 0.43% and 2.73% while 0.28% and 0.94% respectively. From the fitted model, predicted annual wheat area and production for 2016 would be 32.11 million hectares and the 95% CI is 29.38 to 34.84 million hectares where as 99.90 million tones and the CI is 91.14 to 108.67 million tones. Thus the used of UCM is recommended for annual data.

KEYWORDS: Non-stochastic process, trend, UCM, Ljung and Box chi-square.

INTRODUCTION

The forecasting of seasonal time series is a challenging problem. We approach the forecasting challenge from a model-based perspective and adopt the unobserved components time series model. The key feature of this class of models is the decomposition of a time series into trend, seasonal, cyclical and irregular components. Each component is formulated as a stochastically evolving process over time. The decomposition of an observed time series unobserved stochastic processes can provide a better understanding of the dynamic characteristics of the series and the way these characteristics change over time. The trend component typically represents the longer term developments of the time series of interest and is often specified as a smooth function of time.

Box Jenkins and exponential smoothing techniques are commonly used in the analysis of time series in agriculture. Main drawbacks in these models are that, they are suitable only for the stationary series (Box *et al.,* 1994), empirical in nature and fail to explain the underlying mechanism. It is not always possible to create a time-series stationarity by differencing or by some other means. Hence, this approach could be limited to few data sets. Also correlogram, and Partial Auto Correlation Function (PACF) specifying models are not always informative, especially in small samples. This could lead to inappropriate models and predictions.

UCM is a promising alternative approach to overcome these problems (Harvey, 1996). It provides structural time series models and it is a flexible class of models that are useful for forecasting. It decomposes the response series into latent components such as trend, cycle and seasonal effect and linear and nonlinear regression effects. The saline feature of the UCM is latent components, which follow suitable stochastic models and it provides suitable set of patterns to capture the outstanding actions of the response series. UCM can also consist of explanatory variables. Apart from the forecast, structural modeling gives estimates of unobserved components and it is found useful in practical usage. UCM can handle intensive data irregularities too. It is very similar to dynamic models and also popular in the Bayesian time series (West and Harrison, 1999).

In view of the above, the aim of this study is to investigate the possibility of using UCM for modeling

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and forecasting annual area and production in Indian context.

MATERIALS AND METHODS

The secondary data on wheat area (million hectares) and production (million tonnes) for a period of 63 years from 1950-51 to 2013-14 has been collected from the book entitled Agricultural Statistics at a Glance, 2014 published by the Department of Agriculture & Co-operation, Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

Description of the model

A UCM consists of trend, cycle, seasonal and irregular components, and specified of the form (Harvey and Stock, 1993).

$$Y_t = \mu_t + \varphi_t + \omega_t + \varepsilon_t \text{ ; t = 1, 2,.......,n} \quad (1)$$

where μ_t, φ_t, ω_t and ε_t denote the stochastic trend, stochastic cycle, seasonal component and overall error (irregular component), which is assumed to be a Gaussion white noise with variance σ_t^2. Since the data is annual, seasonal effect cannot be identified and thus the UCM for the data can be formulated of the form

$$Y_t = \mu_t + \varphi_t + \varepsilon_t \quad (2)$$

Estimating trend effect

There are two different ways to modeling the trend component in UCM. The first method is by mean of random walk (RW) model, (3). The RW model can be formulated of the form (Harvey and Koopman, 2009).

$$\mu_t = \mu_{t-1} + \delta_t \text{ ; } \delta_t \sim i.i.d \text{ N}(0, \sigma_\delta^2) \quad (3)$$

The second method involves modeling the trend as a Local Linear Trend (LLT), which consists of both level and slope (Harvey, 2001). The trend, μ_t is modeled as a stochastic component with varying level and slope and it can be formulated of the form,

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \delta_t \text{ ; N (0,} \quad (4)$$

$$\beta_t = \beta_{t-1} + \tau_t \text{ ; } \tau_t \sim i.i.d \text{ N } (0, \sigma_\delta^2) \quad (5)$$

where is the slope of the local linear time trend. The disturbances and are assumed to be mutually independent. Special cases of this trend model is obtained by setting one or both of the disturbances variances, and , equal to zero. If is set equal to zero, then the trend becomes linear (fixed slope). If is set to zero, then the subsequent model generally has a smoother trend. If both the variances are set to zero, then the resulting model is the deterministic linear time trend,

$$\mu_t = \mu_0 + \beta_0 t \quad (6)$$

Thus the reduced form of a LLM is the ARIMA (0,2,2) model.

Test for normality and independence of residuals

The Shapiro–Wilks (1965) statistic was used to test whether the residuals are normally distributed or not. The Ljung and Box Chi-square can be used to test the residual auto-correlations are independent or not (Alan, 1983).

RESULTS AND DISCUSSIONS

UCM was employed to fit the trends in area and production of wheat annual data. The findings are discussed in sequence as under.

Identification of trend: The time series plot of annual wheat area and production showed the positive trend.

Linear regression model was employed to the area and production data set of the wheat crop to test whether linear trends exist in the time – series data set or not. The existence of linear trend factor was tested through the linear regression

$$Y = \beta_0 + \beta_1 t + \text{e}$$

where e is the residual which is independently normally distributed with mean zero and variance ó^2 ; Y is the area and production; t is the linear trend factor, â$_0$ and â$_1$ are the intercept and slope respectively.

The hypothesis for testing of linear trend is

$H_0 : \beta_1 = 0$ (Non-existence of linear trend factor)

$H_1 : \beta_1 \neq 0$ (Existence of linear trend factor)

For the area and production of wheat crop the estimated linear trend model is shown in Table-1 and all the estimated parameters values were found to be highly

Table 1. Fitted linear trends for area and production

	Model	R^2 (%)
Area	Y = 10.26* + 0.3254*t + e	94.8*
Production	Y = - 5.437** + 1.4589* t + e	96.9*

significant. There exists positive linear trend in area and production of wheat crop.

Perusal of the time plot (Figures 1 and 2) of India's Wheat area and production data revealed that there is an increasing trend. Here also, the figure exhibits non-stationarity of the upward trend.

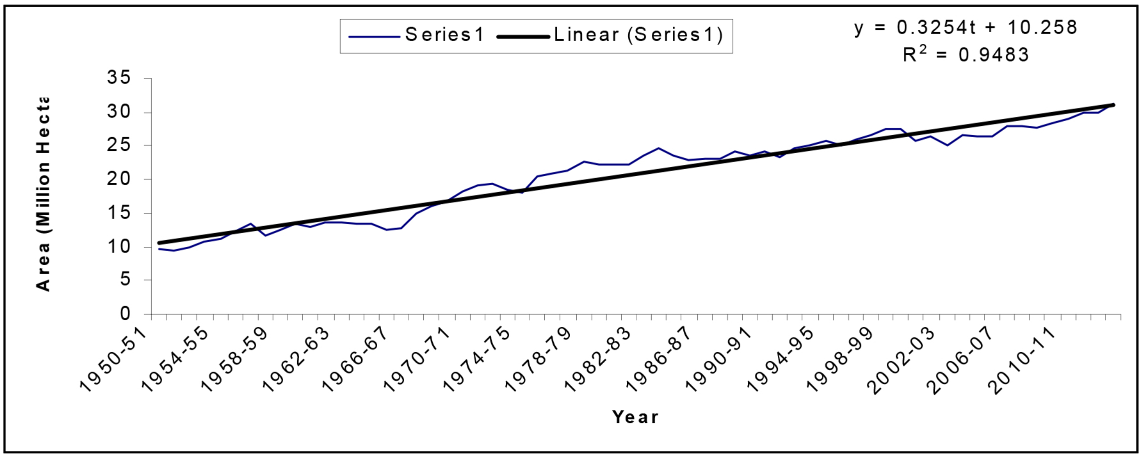

Fig. 1. Time series plot of wheat area (1950-51 to 2013-14)

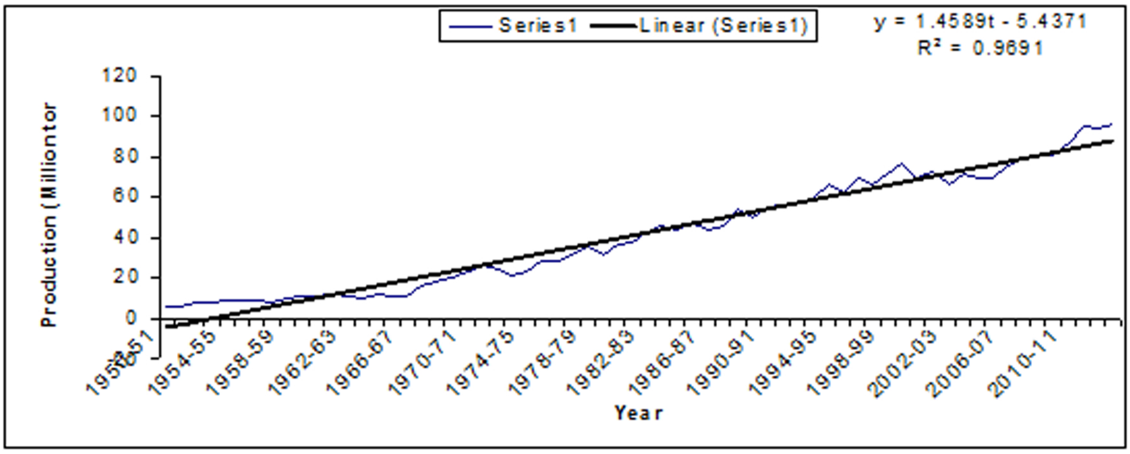

Fig. 2. Time series plot of wheat production (950-51 to 2013-14)

Trend based on UCM model: With this positive trend in the data, all possible components such as cycle and irregular component are tested by using UCM of the form

$$Y_t = \mu_t + \varphi_t + \varepsilon_t$$

At the first stage, analysis was aimed to rectify the existing component in the model by UCM technique. Error variances of the irregular, level and slope components were considered as free parameters of the model and their estimates are shown in Table 2. These estimates, their corresponding t-values and the associated with p – values were used to test the hypothesis of the form,

H_0: Corresponding component is non-stochastic

H_1: Corresponding component is stochastic

The estimates of parameters along with their standard errors have been presented in Table 2 for wheat area and production.

Table 2. Final estimates of the free parameters

Component	Parameter	Estimate	Std. Error	t value	Pr > |t|
Area					
Irregular	Error Variance	0.087	0.105	0.83	0.407
Level	Error Variance	0.564	0.212	2.66	0.008
Slope	Error Variance	0.000	0.000	0.53	0.595
Production					
Irregular	Error Variance	3.417	1.205	2.83	0.006
Level	Error Variance	3.784	1.710	2.21	0.026
Slope	Error Variance	0.020	0.038	0.53	0.595

Table 3. Significance analysis of components

	Components	DF	Chi-Square	Pr > Chi-Sq.
Area	Irregular	1	0.13	0.7192
	Level	1	12584.9	<.0001
	Slope	1	12.84	0.0003
Production	Irregular	1	0.00	0.9565
	Level	1	4072.89	<.0001
	Slope	1	12.75	0.0004

Table 4. Trend information (based on the final state) for area and production of wheat crop

Component	Area		Production	
	Estimate	Standard Error	Estimate	Standard Error
Level	31.09	0.28	95.83	1.50
Slope	0.34	0.09	1.95	0.55

Table 5. Fit statistics based on residuals

	Area	Production
MSE	0.776	10.121
RMSE	0.881	3.181
MAPE	3.790	7.547
Maximum Percent Error	12.984	29.695
R – Square	98%	99%
Adjusted R – Square	98%	99%

Table 2, reveals that for the area, the disturbance variance of irregular and slope components were found to be non-significant whereas the level component was significant. In the case of production irregular and the level components error variances were found to be significant and the slope component was non-significant.

The slope component was non-significant in area and production of wheat crop and the estimates suggested that the slope can be treated as constant, i.e., has zero variance. Since the slope component was non-significant, it might be useful to check if it could be dropped from the model. This could be checked by examining the significance analysis of the components.

The significant analysis of component helps to decide if slope can be dropped from the model after testing the following hypothesis,

H_0 : Given component is non-significant

H_1 : Given component is significant

The goodness of fit of the analysis of components is shown in the Table 3.

The results observed from the Table 3, the slope component was significant; it could not be dropped from the model and could be made deterministic by holding the value of its error variance fixed at zero. Also the level component was significant and cannot be dropped from the model, thus the model is a stochastic model. The contribution of irregular component is insignificant, but since it is a stochastic component, it cannot be dropped from the model.

Now the slope variance is fixed and free parameters are estimated and given in the Table 4.

After fixing the slope, the MSE, RMSE, MAPE and MPE values were calculated and presented in the Table 5. The highest adjusted R^2 was obtained for production (99%) followed by area (98 %). The adjusted R^2 for the estimated model has shown the closeness of the estimates to the actual value.

Brintha *et al.,* (2014) employed UCM model for forecasting coconut production in Sri Lank during the period from 1950–51 to 2012-13. Their results revealed that both the trend components, level and slope, have non-stochastic process. Further, it revealed that the level was significant and slope was insignificant.

Residual analysis: The results presented in the Table 6 revealed that, the residuals due to UCM model were normally distributed for area and production, since the Kolmogorov-Smirnov as well as Shapiro – Wilks test statistics values were found to be non-significant at 5% level of significance.

The Ljung – Box test was applied to the residuals of the fitted model. Results are shown in Table 7. The results reveal that all p-values at different lags exceeded 0.05 which indicated that the acceptance of model accuracy at 95 % level.

Forecasting: The forecasted values of area and production by using UCM model are given Table 8, respectively along with 95% Confidence Limits. The first four forecast values are just to compare with the observed series to get an idea of the quality of the forecast. The residuals were found to be very small. The forecast's values were very close to the actual data. This implies that the model specification is adequate.

From the Table 8 it is observed that forecast using UCM shows an increasing trend for area and production of Wheat. The validity of these forecasts can be checked when the actual data is available for the lead years. The trends in area and production are depicted in the Figures 4 and 5 respectively.

CONCLUSION

UCM with slope variance seems to fit the annual wheat area and production data well. Forecasted error percentage for the year 2012-13 and 2013-14 for wheat area 2.73 while 0.94 respectively. Obtained model predicted the annual wheat area of 30.34 million hectares and the 95 % CI is from 28.66 to 32.03 where as production is 95.01 million tones with CI is from 88.80 to 101.21. Adjusted R^2 for the estimated model was reveals the closeness of the estimates to the actual (observed) value. The results revealed that an increasing trend has been observed in area and production of wheat crop in India. UCM models can effectively be utilized for the time series modeling of agricultural crop area and production, especially that are of non-stationary.

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Table 6. Tests of normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Area	0.109	62	0.066	0.976	62	0.259
Production	0.077	62	0.200(*)	0.982	62	0.495

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

Table 7. Ljung – Box test results for residuals from the fitted UCM model

Lags	Area		Production	
	Chi-Square	p –value	Chi-Square	p – value
2	0.424	0.809	1.258	0.533
4	1.398	0.845	2.538	0.638
6	1.924	0.927	6.381	0.382
8	2.832	0.944	6.398	0.903
10	5.199	0.877	11.080	0.351
12	5.774	0.927	11.324	0.501
14	6.040	0.965	12.679	0.552
16	9.893	0.872	14.395	0.569

Table 8. Forecasts of area and production of wheat (2010-11 to 2016 –17)

Area					
Year	Observed	Estimated	95 % Confidence Limits		Absolute % error
			Lower	Upper	
2010-11	29.07	28.74	27.05	30.43	1.14
2011-12	29.86	29.35	27.67	31.04	1.71
2012-13	30.00	30.13	28.44	31.82	0.43
2013-14	31.19	30.34	28.66	32.03	2.73
2014-15	-	31.43	29.74	33.12	
2015-16	-	31.77	29.51	34.03	
2016-17	-	32.11	29.38	34.84	
Production					
Year	Observed	Estimated	95 % Confidence Limits		Absolute % error
			Lower	Upper	
2010-11	86.87	82.26	76.05	88.47	5.31
2011-12	94.88	86.76	80.55	92.97	8.56
2012-13	93.51	93.77	87.56	99.98	0.28
2013-14	95.91	95.01	88.80	101.21	0.94
2014-15	-	97.05	90.85	103.26	
2015-16	-	98.48	90.90	106.05	
2016-17	-	99.90	91.14	108.67	

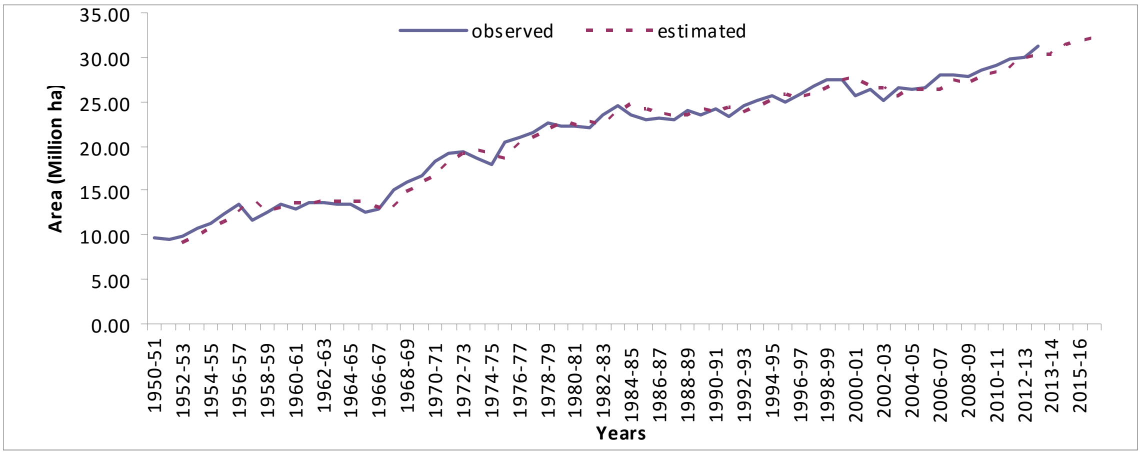

Fig. 3. Observed and estimated values of wheat area in India

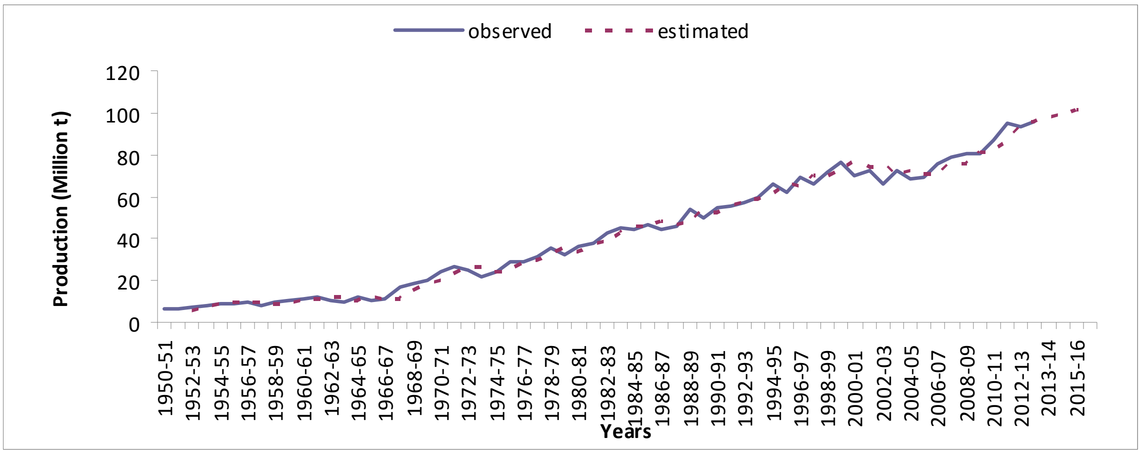

Fig. 4. Observed and estimated values of wheat production in India

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EFFECT OF WEED CONTROL PRACTICES UNDER SYSTEM OF CROP INTENSIFICATION (SCI) ON YIELD AND QUALITY OF SESAME (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted to evaluate the “System of Crop Intensification (SCI) practices in Sesame” at Wetland farm of Tamil Nadu Agricultural University, Coimbatore during the early summer season (January to May, 2013) in Randomized complete block design with ten treatments and three replications. Among the different treatments, sesame grown under 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + HW at 35 DAS recorded lower density (7.33 m^{-2}) and dry weight of weed at 60 DAS (1.47 g m^{-2}), higher seed and oil yield (1.137 t ha^{-1} and 502 kg ha^{-1}, respectively). Weed management practices under study *viz*., hand hoeing and mechanical weeding did not influence the oil content of sesame.

KEYWORDS: Sesame, SCI, Hand weeding, Mechanical weeding, Yield and Quality.

INTRODUCTION

In India, sesame (*Sesamum indicum* L.) ranks second in importance next to groundnut amongst oilseed crops. Being a slow growing crop during the early phase, weeds compete with sesame for growth resources and affect the growth of sesame and finally reducing the production unit area^{-1}. To reduce the weed competition, some of the agronomical measures like higher plant density per hectare and timely weeding by using hand hoes and mechanical weeders can help to boost the production unit area^{-1} of the crop (Narkhede *et al*., 2000). Present experiment was carried out with the objective to evaluate the effect of weed management practices under System of Crop Intensification (SCI) on yield and quality of sesame.

MATERIALS AND METHODS

A field experiment was conducted during the early summer season (January to May, 2013) at Wetland farm of Tamil Nadu Agricultural University, Coimbatore, to evaluate the System of Crop Intensification (SCI) practices in sesame. The soil of the experimental field was clay loam in texture belonging to *Typic Haplustalf*. The experiment was laid out in Randomized complete block design, comprised of ten treatments *viz*., 30 × 30 cm spacing + No nipping + hand weeding (HW) at 35 DAS (Control), 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + HW, 40 × 40 cm spacing + Nipping at 35 DAS + HW, 40 × 40 cm spacing + Nipping at 35 DAS + mechanical weeding (MW), 40 × 40 cm spacing + TIBA @ 50 ppm at 30 DAS + HW, 40 × 40 cm spacing + TIBA @ 50 ppm at 30 DAS + MW, 50 × 50 cm spacing + Nipping at 35 DAS + HW, 50 × 50 cm spacing + Nipping at 35 DAS + MW, 50 × 50 cm spacing + TIBA @ 50 ppm at 30 DAS + HW and 50 × 50 cm spacing + TIBA @ 50 ppm at 30 DAS + MW. The treatments were replicated thrice. Sesame variety VRI (SV) 2 was used as test cultivar. Recommended dose of fertilizers *i.e.,* 35:23:23: NPK kg/ha was applied as basal.

Application of pendimethalin @ 1.0 kg a.i. ha^{-1} as pre-emergence herbicide to all treatments was done on 3 DAS. Both hand and mechanical weeding were done using hand hoe and self-propelled power weeder (weeder details include: name of the weeder- Baby weeder, power source – 1.5 hp petrol engine, depth of cut- 5-6 cm, width of operation- 22.5 cm, speed- 1.8kmph, coverge- 0.084 ha day^{-1} and fuel consumption- 0.660 lit hr^{-1}) as per the treatment schedule on 35 DAS, respectively. Data on density and dry weight of weed, yield and quality parameters were recorded and statistically analysed.

RESULTS AND DISCUSSION

Treatments imposed had profound effect on weed density and weed dry weight due to SCI practices in sesame. Lesser weed density (7.33 m^{-2}) and weed dry weight (1.47 g m^{-2}) was noticed at 60 DAS under 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + HW over

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Table 1. Effect of weed control practices under System of Crop Intensification (SCI) on weed growth, yield and quality parameters of sesame

Treatments	Weed density (No. m^{-2}) at 60 DAS	Weed dry weight (g m^{-2}) at 60 DAS	Seed yield (t ha^{-1})	Oil yield (kg ha^{-1})	Oil content (%)
T_1 : 30 × 30 cm spacing + No nipping + HW at 35 DAS –Control	3.15 (8.00)	1.88 (1.55)	0.793	358	45.2
T_2 : 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + HW at 35 DAS	3.05 (7.33)	1.86 (1.47)	1.137	502	44.2
T_3 : 40 × 40 cm spacing + Nipping at 35 DAS + HW at 35 DAS	4.68 (20.00)	2.43 (3.90)	0.822	381	46.4
T_4 : 40 × 40 cm spacing + Nipping at 35 DAS + MW at 35 DAS	4.15 (15.33)	2.16 (2.69)	1.022	468	45.8
T_5 : 40 × 40 cm spacing + TIBA @ 50 ppm at 30 DAS + HW at 35 DAS	4.95 (22.67)	2.44 (3.96)	0.763	345	45.2
T_6 : 40 × 40 cm spacing + TIBA @ 50 ppm at 30 DAS + MW at 35 DAS	4.22 (16.00)	2.12 (2.49)	0.803	363	45.2
T_7 : 50 × 50 cm spacing + Nipping at 35 DAS + HW at 35 DAS	5.40 (27.33)	2.62 (4.86)	0.775	353	45.6
T_8 : 50 × 50 cm spacing + Nipping at 35 DAS + MW at 35 DAS	4.69 (20.00)	2.17 (2.72)	0.944	418	44.3
T_9 : 50 × 50 cm spacing + TIBA @ 50 ppm at 30 DAS + HW at 35 DAS	5.48 (28.00)	2.47 (4.14)	0.812	380	46.9
T_{10} : 50 × 50 cm spacing + TIBA @ 50 ppm at 30 DAS + MW at 35 DAS	4.82 (21.33)	2.19 (2.78)	0.997	459	46.1
SEd	**0.25**	**0.12**	**40**	**20**	**2.4**
CD (P=0.05)	**0.53**	**0.24**	**84**	**42**	**NS**

* Values in parenthesis are original. Weed data was transformed to square root transformation.

* HW: Hand weeding; MW: Mechanical weeding; TIBA: Tri iodo benzoic acid; NS: Non-significant

other treatments (Table 1). This was due to the quick growth of sesame than weeds after weeding at 35 DAS which resulted in higher plant dominance over weeds. Shading of ground area was observed in closer square geometry due to more number of plants m^{-2} and coverage of row spacing by spreading branches and leaves. Similar results were reported by Narkhede *et al*. (2000) in sesame.

Effect of SCI practices brought out a significant influence on seed yield of sesame. Among the treatments, 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + Hand weeding at 35 DAS had shown its superiority over other treatments in recording higher seed yield (30.25% higher over control). Higher seed yield could be due to better weed control during critical stage and more plant population m^{-2}. These results are in conformity with the findings of Tripathi *et al*. (2009) in pigeonpea.

Oil content is largely governed by genetic nature. The weed management practices under study *viz*., hand hoeing and mechanical weeding did not influence the oil content of sesame. These findings are in support of Ahmad *et al*. (2002) in sesame (Table -1).

Square planting with 30 × 30 cm spacing + TIBA @ 50 ppm at 30 DAS + HW at 35 DAS gave higher oil yield (502 kg ha^{-1}) than other treatments. Since, oil content values were not varied much, the impact of seed yield had a marked effect on oil yield of sesame. The results are in line with Ahmad *et al*. (2002) in sesame.

CONCLUSION

Sesame grown under 30 × 30 cm spacing, TIBA @ 50 ppm at 30 DAS and hand weeding at 35 DAS recorded lower density and dry weight of weed at 60 DAS, higher seed and oil yield.

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ANALYZING COMPOUND GROWTH RATES AND MARKETING EFFICIENCY IN TRANSACTING MAIZE IN KURNOOL DISTRICT OF ANDHRA PRADESH

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ABSTRACT

In view of the potentiality of maize crop in Kurnool district, the analysis pertaining to growth performance and marketing aspects has assumed greater significance. Regarding growth performance of maize in Kurnool district, improvement in irrigation facilities like Telugu Ganga project and K.C canal command and popularization of drip irrigation facilities have contributed much towards the drastic increase in area under maize. The Compound Growth Rate (CGR) analysis revealed that, the increase in production of maize was mainly due to increase in area under cultivation rather than productivity in Kurnool district. Among the two marketing channels identified in transacting maize in Kurnool district, Channel-II was found to have higher MEI when compared with Channel-I. The Government should construct roads for easy transport of produce to the market centres. Instead of transporting the produce individually from the farm gate to the district market centre, it is essential to establish a loading station in the vicinity of the villages, so as to assemble the produce at loading station and transport it to the market centre on cost effective basis.

KEYWORDS:

The predominant maize growing states that contributes more than 80% of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%), Himachal Pradesh (4.4%). Apart from these States, maize is also grown in Jammu and Kashmir and North-Eastern states. Hence, the maize has emerged as important crop in the non-traditional regions i.e. peninsular India as the state like Andhra Pradesh which ranks 5th in area (0.79 m.ha) has recorded the highest production (4.14 m.tonnes) and productivity (5.26 t ha^{-1}) in the country although the productivity in some of the districts of Andhra Pradesh is more or equal to the USA (Chauhan, 2013). Area under hybrid seeds in 2013-14 is estimated to be around 60 per cent of the total area under maize cultivation. Andhra Pradesh has the highest productivity followed by Tamil Nadu due to majority of the area being covered under Single Cross Hybrids (SCH).

In Andhra Pradesh, maize has emerged as one of the major cereal crops in 3.52 lakh ha with an annual production of 22.1 lakh tonnes in 2013-2014. Kurnool district with an area of 0.52 lakh ha enjoy a production of 3.1 lakh tonnes in the same year thereby, accounting for 14.77 and 14.02 per cent share respectively at Andhra Pradesh level. Kurnool district in Andhra Pradesh had got good reputation as an important maize grower of Andhra Pradesh since long time. In view of the potentiality of maize crop in Kurnool district, its economic analysis has assumed greater significance. From this background, it emanates the need for an in depth microscopic study on analyzing the growth performance and marketing aspects in maize cultivation in Kurnool district. The results of the study would be useful to maize farmers of Kurnool district in particular and of Andhra Pradesh in general in planning suitable strategies for efficient marketing of maize. Keeping this goal in view, the following specific objectives were formulated for this in-depth investigation.

1. To analyse the growth performance of maize at All India level, Andhra Pradesh and Kurnool district.
2. To study the marketing channels and compute price spread in transacting maize in Kurnool district of Andhra Pradesh.

MATERIALS AND METHODS

Kurnool district in Andhra Pradesh was purposively selected for the study, as the district ranks first in the

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cultivation of maize in Rayalaseema region of Andhra Pradesh state after its bifurcation during 2013-14. Top two mandals in terms of area under maize cultivation in Kurnool district viz., Nandikotkur and Pamulapadu were selected. From the list of villages arranged in descending order of acreage under maize, top two villages from each mandal were selected. For the selection of farmers, a list of farmers from the selected villages was obtained from the respective Gram Panchayat Offices. To analyze the resource use efficiency, the farmers were conveniently categorized according to their land holding size i.e., Marginal (<1 ha), Small (1-2 ha) and Other farmers (>2 ha). From these three different categories, a total of 120 farmers were selected at random based on probability proportional to size. So, the sampling frame consists of one district, two mandals, four villages and 120 farmers which forms the basis to elicit the requisite data. A well structured pre-tested schedule was employed to collect the requisite information from the sample farmers. The study was conducted in the year 2013-14. To analyze the growth performance of maize, Compound Growth Rates (CGRs) were worked out for area, production and productivity of maize at All India level, Andhra Pradesh and with special reference to Kurnool district for two sub periods i.e., 1980-1994 (Pre-WTO regime) and 1995-2014 (Post-WTO regime) and also during over all period (1980-2014) by employing exponential function of the following form:

$$Y_t = ab^t$$

The above equation was transformed into log linear form and written as:

$$\log Y = \log a + t \log b + \log \mu_t$$

where,

Y_t: Area / Production / Productivity of maize during the selected reference period,

't' : Years which takes value 1, 2…………n,

μ_t: Disturbance term in year 't',

'a' and 'b' are constant and parameters to be estimated respectively.

The above equation was estimated by using Ordinary Least Squares (OLS) technique.

$$CGR = \text{antilog of } (\log b - 1) \times 100$$

where, log b is the parameter estimated

To study the price spread and other relevant parameters of estimating marketing efficiency in transacting maize, the following formulae are employed:

Price spread = Consumer Purchase Price (CPP) – Farmer's Net Selling Price(FNSP)

or

Gross Marketing Margins (GMMs) of all market intermediaries + Marketing cost (Mc) incurred by the farmer

Total Marketing cost = Mc of farmer + ΣMc_n

where, Mc_n = Marketing costs incurred by n intermediaries

$n = 1, 2, 3……………….n$

Gross Marketing Margin$_i$ (GMM_i) = $SP_i - PP_i$

Net Marketing Margin$_i$ (NMM_i) = $GMM_i - Mc_i$

where,

GMM_i = Gross Market Margin of i^{th} intermediary

SP_i = Selling Price of i^{th} intermediary

PP_i = Purchase Price of i^{th} intermediary

Mc_i = Marketing costs incurred by i^{th} intermediary

Computation of Marketing Efficiency Index (MEI)

The following measures were employed to assess the MEI without considering Marketing Losses:

Shepherd's approach: MEI = (V/I) -1

where,

V = Value of commodity sold at the consumer's level or CPP

I = Mc incurred by all the agencies

Acharya's approach: MME = [FNSP / (Mc + MM)]

where,

MME = Modified Measure of Marketing Efficiency

FNSP = Farmer's Net Selling Price

Mc = Marketing cost incurred by all the intermediaries

MM = Marketing Margins incurred by all the intermediaries

Table 1. CGRs of Area, Production and Productivity of Maize

Period	India			Andhra Pradesh			Kurnool		
	Area	Production	Productivity	Area	Production	Productivity	Area	Production	Productivity
1980-1994	0.13^{NS}	3.04**	2.90**	-0.22^{NS}	2.19^{NS}	2.55^{NS}	5.15^{NS}	4.05^{NS}	-1.03^{NS}
1995-2014	2.38**	5.13**	2.68**	4.60**	8.54**	3.69**	29.80**	37.04**	5.57**
1980-2014	1.36**	3.89**	2.49**	3.36**	7.26**	3.80**	19.64**	23.70**	3.39**

*: Significant at 5 per cent level; **: Significant at 1 per cent level; NS: Non-significant.

Table 2. Marketing channels followed by different sized farms in marketing of maize

S. No.	Size groups	Channel I	Channel II	Total
1	Marginal	37 (60.66)	24 (39.34)	61 (100)
2	Small	19 (55.88)	15 (44.12)	34 (100)
3	Other	16 (64.00)	9 (36.00)	25 (100)
4	Total	72 (60.00)	48 (40.00)	120 (100)

Figures in parentheses indicate percentages to the respective column totals

RESULTS AND DISCUSSION

i. Growth rates in area, production and productivity of maize

CGRs were worked out to study the growth rates in area, production and productivity of maize at All India level, Andhra Pradesh and with special reference to Kurnool district for an overall reference period (1980-2014) and during two sub periods 1980-1994 (Pre-WTO Regime) and 1995-2014 (Post-WTO Regime) (Table 5.4). At All India level for the overall reference period, i.e., 1980-2014, there was significant increase in the growth of both area (1.36%) and productivity (2.49%) of maize and hence, production of maize showed positive and significant growth rate of 3.89 per cent. Regarding the sub-period, during pre-WTO regime (1980-1994), area under maize showed non-significant positive growth trend (0.13%), but it was compensated by significant growth in productivity (2.90%) and thereby, production showed positive and significant growth rate at 3.04 per cent. Regarding post-WTO regime, both area and productivity of maize showed positive and significant growth rates (2.38 and 2.68 per cents respectively) and hence, production showed positive and significant growth rate at 5.13 per cent. Thus, during both Pre and post-WTO regimes, productivity growth contributed much towards maize production compared to area growth. However, comparing pre and post WTO regimes, area growth under maize showed significant influence in boosting maize production during post-WTO regime. This signifies the expansion of area under maize especially under irrigation commands and favourable domestic and international prices of maize have led to higher and significant influence on maize production during Post-WTO regime. This higher influence of area growth on maize production was clearly witnessed in Andhra Pradesh state during the overall reference period and even during post-WTO regime. During pre-WTO regime, area under maize showed declining trend (-0.22%) and productivity growth was insignificant (2.55%) and this led to insignificant growth in production (2.19%). This low area and productivity growths of maize can be attributed towards inadequate irrigation facilities and lack of high yielding varieties of maize during this reference period. However, during post-WTO regime, there was drastic increase in area under maize (4.60%) at significant level and this coupled with positive and significant growth in productivity (3.69%) has led to positive and significant growth in production (8.54%). These positive trends were mainly due to popularization of high yielding varieties of maize, improvement in irrigation facilities and strong acreage response from farmers for the price signals of

Table 3. Price spread in transacting maize by the sample farmers without Considering marketing losses at different marketing agencies

Items	Channel I ₹ / qtl	Channel II ₹ / qtl
Farmer's Net Selling Price	964.58 (84.60)	1256.03 (92.54)
Total Mc incurred by the farmer	67.36 (5.91)	54.23 (4.00)
Farmer's Selling Price / Wholesaler's Purchase Price / MARKFED Purchase Price	1031.94 (90.50)	1310.26 (96.53)
Total Marketing cost incurred by the wholesaler/ MARKFED	58.91 (5.17)	18.03 (1.33)
Gross Marketing Margin of wholesaler	72.31 (6.34)	24.92 (1.84)
Net Marketing Margin of wholesaler	13.4 (1.18)	6.89 (0.51)
Wholesaler's selling price/ MARKFED selling price/ poultry feed unit purchase price/ Co-operative diary Purchase Price	1104.25 (96.85)	1335.18 (98.37)
Total Marketing cost incurred by the Poultry feed unit/Co-operative diary	19.58 (1.72)	11.51 (0.85)
Gross Marketing Margin of Poultry feed unit	24.16 (2.12)	22.12 (1.63)
Net Marketing Margin of Poultry feed unit	4.58 (0.40)	10.61 (0.78)
Poultry feed unit selling price/ Co-op. Diary selling price/ Retailer's purchase price/ consumer's purchase price	1128.41 (98.96)	1357.30 (100)
Total Mc incurred by the retailer	11.44 (1.00)	-
GMM of retailer	11.81 (1.04)	-
NMM of retailer	0.37 (0.032)	-
Retailer's Selling Price / Consumer's Purchase Price	1140.22 (100.00)	-
Price spread or Total GMMs of all the agencies +Mc incurred by the farmer	175.64	101.27

Figures in parentheses indicate percentages to the respective consumer's purchase price

Table 4. Indices of marketing efficiency in the selected marketing channels

S. No.	Method	Channel –I	Channel-II
1	Shepherd's method	6.25	15.20
2	Acharya's method	5.49	12.40

maize both in domestic and international markets. These positive influences in terms of growth rates of area, production and productivity of maize during Post-WTO regime have also contributed towards the growth in area (3.36%), production (7.26%) and productivity (3.80%) during the overall reference period. Prabakaran and Sivapragasam (2013) studied the Compound growth rates in rice and sorghum for the period 1970-71 to 1999-2000 and found that with respect to area, production and yield of rice, they are positive at the state and regional level for all the periods and the total periods except rayalaseema where it has shown negative growth rate. In case of sorghum, the compound growth rates of area and production were negative and showed positive effect in the yield.

In contrast to Andhra Pradesh, in Kurnool district, during Pre-WTO regime, productivity showed declining trend (-1.03%) and area though showed positive growth rate (5.15%), but remained non-significant. Hence, production growth (4.05%) also remained non-significant. However, during Post-WTO regime, there is drastic increase in area under maize (29.80%) and productivity also showed positive and significant growth rate of 5.57 per cent and hence, the production of maize showed positive and significant growth rate of 37.04 per cent. This signifies that, the increase in irrigation facilities like Telugu ganga project and K.C canal command and popularization of drip irrigation facilities have contributed much towards the drastic increase in area under maize during Post-WTO regime when compared to Pre-WTO regime. The healthy performance of maize in terms of growth in area, productivity and production during Post-WTO regime also influenced towards positive and significant growth rates of maize area (19.64%), productivity (3.39%) and production (23.70%) during the overall reference period.

ii. Price spread and Marketing efficiency in transacting maize

The following two important channels were identified in the marketing of maize in Kurnool district:

Channel-I

Producer ➢ Commission agent ➢ Wholesaler ➢ poultry feed unit ➢ Retailer ➢ Poultry units

Channel-II

Producer ➢ MARKFED ➢ Co-operative diaries ➢ Consumer (sale of animal feed)

Among the two marketing channels, the most commonly used marketing channel for transacting maize was Channel-I. This is evident from the Table 5.15, as 60.00 per cent of the total sample farmers sold their produce through this channel. The proportion of marginal, small and other farmers who used this channel for transacting maize was 60.66, 55.88 and 64.00 per cents respectively. Channel II was followed by 40 per cent of the total selected farmers. The proportion of marginal, small and other farmers following this channel was 39.34, 44.12 and 36.00 per cents respectively.

Price Spread in Maize Marketing

Channel-I

The details of Table 3 reveal that, the Farmer's Share in Consumer's Rupee was 84.60 per cent. In this channel, the farmer incurred marketing costs of ₹ 67.36 per quintal of maize and realized a net selling price of ₹ 964.58. The marketing costs, GMM and NMMs of the wholesaler were ₹ 58.91, ₹ 72.31 and ₹ 13.40 respectively per quintal of maize and the corresponding figures for poultry feed unit were ₹ 19.58, ₹ 24.16 and ₹ 4.58 respectively. The retailer's were ₹ 11.44, ₹ 11.81 and ₹ 0.37. The NMMs of the wholesaler, poultry feed unit and retailer accounted for 1.18, 0.40 and 0.032 per cents of the consumer's rupee respectively.

The farmer on an average incurred a total of ₹ 67.36 in marketing of one quintal of maize. Among the total marketing costs incurred by the farmer, loading was the major cost accounted for 76.78 per cent followed by commission and weighing accounting for 15.32 and 7.90 per cents respectively. The wholesaler purchased the produce from the farmer through a commission agent and incurred an amount of Rs. 58.91 towards marketing costs. The major cost component of wholesaler is loading cost of ₹ 26.68 which accounted for 45.29 per cent of the total cost incurred by the wholesaler. Other costs such as transportation, cess charges and unloading accounted for 24.99, 18.74 and 10.98 per cents respectively. The poultry feed unit purchased from the wholesaler and incurred ₹ 19.58 of the total marketing costs. Transportation cost was ₹ 12.40 which accounted for 63.33 per cent and unloading cost, ₹ 7.18 which accounted for 36.67 per cent. For the retailer, the marketing costs incurred were loading (₹ 6.16) and unloading costs (₹ 5.28) accounting for 53.85 and 46.15 per cents respectively of total marketing costs.

Channel-II

The analysis of marketing costs and margins (Table 3) indicated that, the farmer realized a net selling price of ₹ 1256.03 per quintal of maize accounting for 92.54 per cent of the price paid by the consumer. The marketing cost incurred by the farmer was ₹ 54.23. After deducting all expenses, the MARKFED earned a NMM of ₹ 6.89 which accounted for 0.51 per cent of consumer's rupee. The co-operative dairy purchased maize at a price of ₹ 1335.18 per quintal and sold to the consumer for a price of ₹ 1357.30. In this process, it made a NMM of ₹ 10.61 accounting for 0.78 per cent of the consumer's rupee.

The total marketing costs incurred by the farmer was ₹ 54.23 (Table 3). Among these marketing costs, loading charges was the major cost incurred by the farmer accounting for 92.40 per cent of total marketing costs incurred followed by weighing, accounted for 7.60 per cent. The farmers sold the produce to the MARKFED and it incurred different marketing costs like transportation, stacking and packing, unloading and processing and they accounted for 41.93, 35.94, 18.69 and 3.44 per cents respectively. The co-operative dairy purchased the feed from the MARKFED and incurred total marketing cost of ₹ 11.51 in which loading and unloading costs accounted for 55.34 and 44.66 per cents respectively.

From the above discussion, it is clear that, the marketing costs incurred by the farmer is highest than all other intermediaries across the two channels.

From the forgoing analysis, it can be inferred that the farmer was getting the highest share of CPP in Channel-II (92.54%) over Channel-I (84.60%). Price spread is more in Channel-I (Rs. 175.64) than Channel-II (Rs. 101.27) indicating Channel-II was more efficient than Channel-I.

Marketing Efficiency

It is seen from the Table 4 that, the index of marketing efficiency was higher in channel-II i.e., 15.20 and 12.40 both in Shepherd's method and Acharya's method respectively indicating that channel-II was more efficient than channel-I. The inefficiency in channel-I was due to higher marketing costs and margins involved in the marketing of maize.

SUMMARY AND CONCLUSIONS

The study infers that, regarding growth performance of maize, significant area and productivity growth rates of maize at All-India level, in Andhra Pradesh and in Kurnool district were influential in boosting the production of maize during overall reference period. The improvement in irrigation facilities like Telugu Ganga project and K. C canal command and popularization of drip irrigation facilities have contributed much towards the drastic increase in area under maize during Post-WTO regime when compared to Pre-WTO regime. This healthy performance of maize in terms of growth in area, productivity and production during Post-WTO regime also influenced towards positive and significant growth rates of maize area (19.64%), productivity (3.39%) and production (23.70%) during the overall reference period. Thus, the CGR analysis revealed that, the increase in production of maize was mainly due to increase in area under cultivation rather than productivity in Kurnool district. Among the two marketing channels identified in transacting maize in Kurnool district, Channel--II was found to have higher MEI when compared with traditional Channel-I. In view of this, the Government should construct approach roads for easy transport of produce to the market centers and involve MARKFED and cooperatives. Instead of transporting the produce individually from the farm gate to the district market centre, it is essential to establish a loading station in the vicinity of the villages, so as to assemble the produce at loading station and transport it to the market centre on cost effective basis.

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PERCEPTION OF THE FARMERS ON THE USE OF DRUMSEEDER IN CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Direct seeding in Rice using drumseeder was introduced by Krishi Vigyan Kendra during 2006 in Chittoor district of Andhra Pradesh to address problems like shortage of labour, increased cost of cultivation and to augment the productivity with judicious use of resources. The area under drumseeder method escalated to 4621.2 ha by the year 2012 from just 0.2 ha in 2006. A study was conducted in Chittoor district in 2014 to understand the perception of farmers about drumseeder method with a sample size of 160 respondents who practiced it. They perceived that drumseeder method is farmer friendly, technically and economically feasible to all categories of farmers and can be taken up in any season. They expressed that the cost of cultivation is very much reduced in addition to saving in resources like human labour, water and inorganic fertilizers. The respondents gave some suggestions for upscaling drumseeder method among the farming community. The 'master trainer' concept helped in large scale dissemination and adoption of drumseeder technology in the district and supplemented the efforts of extension agencies. Hence this method may be popularised in feasible areas through capacity building programmes and providing incentives for the farmers.

KEYWORDS: Direct seeding, Rice, Drumseeder, Traditional transplanting, Productivity, Resources

Prologue

In global scenario, rice is the most common staple food for about 3 billion people and receives an estimated 24-30 percent of the world's developed freshwater resources (Satyanarayana *et al.* 2007; Sudeep 2010). The world's population is increasing and there has been more concern towards food security but is challenged by increasing food demand with declining water availability (Farooq *et al.*, 2009; Sudeep 2010). To meet the demand of growing population, the production of rice needs to be multiplied to a great extent. According to Zheng *et al.*, (2004) farmers have to grow 50 percent more rice in 2025 in order to assure food security in rice-consuming countries.

According to the Directorate of Economics and Statistics, India, the area under rice cultivation in the country which was 44.67 million ha in 2001-02 declined to 43.95 million ha in 2013-14. In Andhra Pradesh state, the area under rice was 4.243million ha during 2000-01 and it gradually shrinked to 4.096 million ha by 2011-12.

The trend of area under rice cultivation in Chittoor district of Andhra Pradesh is not different from that of the country and Andhra Pradesh as it is declined to 51106 ha in 2011-12 from 104400 ha in 1998-99 to 75218 ha in 2010-11 (Directorate of Economics and Statistics, India). In the recent years, rice farming has become non-remunerative due to increased cost of cultivation, low market prices and diminished farm profits. The major reason for increased cost of cultivation in rice is increased cost of transplanting and weeding operations. The shortage of farm labour supply in irrigated areas, particularly in the peak season and the raise in wage rates significantly affected farming activities particularly during transplanting, weeding and harvesting operations.

During *rabi* 2006, Krishi Vigyan Kendra, Chittoor for the first time introduced direct seeding method in rice using a fibre bodied eight rowed drumseeder developed by Tamil Nadu Agricultural University (TNAU). After the success of the assessment trial in a farmer named Nageswarrao's field at Madibaka village, Yerpedu mandal of Chittoor district, RASS-KVK popularised the technology through capacity building programmes, front line demonstrations, field days, exposure visits, mass media, and publication of literature and digitalization of the technology. Direct seeding is helpful due to less labour and time requirement, low cost of cultivation due to

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skipping of nursery raising and transplanting, maintaining recommended plant population and also due to early crop maturity by 7 -12 days (Subbaiah *et al.,* 2002; Gill, 2008; Manjunatha 2009). The area under drumseeder method improved gradually over the years.

Perception of farmers towards direct seeding technology

The decision of use of technologies is dependent on how farmers perceive of technology. According to Van de Ban and Hawkin (1988), perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness., the predominant role of technology is facilitating major improvement in agriculture productivity (Truong Thi Ngoc Chi, 2002 and Koppel (1978). Therefore, it is important to know how farmers perceived technologies for better understanding of their choice in adoption or not.

A study was conducted in Chittoor district of Andhra Pradesh to understand the response of farmers in terms of production aspects, perceptions of farmers on the drumseeder technology in rice, source of information about the technology and their suggestions for upscaling of the technology.

METHODOLOGY

The present study is conducted purposively in the eastern part of Chittoor district where large area under drumseeder method is practiced. Among the five agricultural divisions in eastern part of the district, one mandal from each division viz., Renigunta from Tirupati division, Yerpedu from Sri Kalahasthi division, Karvetinagaram from Nagiri division, R.C.Puram from Puttur division and Varadaiahpalem from Satyavedu division are selected for the study as shown in Fig 1. One village from each mandal is selected randomly where drumseeder is practiced. Care is taken to select those respondents from these five villages who practiced this method atleast once.The study is conducted during the year 2014. The total number of respondents selected for the study is 160 and the data is collected though personal interview using a schedule. Descriptive statistics is used to summarize data in the forms of mean and percentage.

The components of the study include age of the respondents, experience in drumseeder method, continuance/discontinuance of the practice, perception of the respondents on the drumseeder method of rice

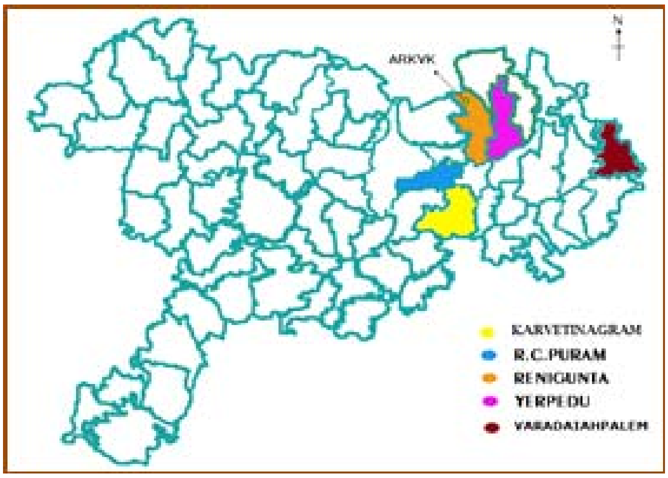

Fig. 1. Chittoor district map showing mandals where study was done

cultivation, suggestions for upscaling the drumseeder method, ranking of the rice cultivation methods and the source of the drumseeder technology to the respondents.

About 14 statements covering the all aspects of drumseeder method are prepared in consultation with the experts of Agronomy, Agricultural Extension of Acharya N G Ranga Agricultural University, line department officials, progressive farmers and Scientists of KVK. The results on the perceptions are presented in the form of frequencies and percentages.

Suggestions given by the respondents to upscale the drumseeder method are presented in the form of frequencies and percentage.

RESULTS AND DISCUSSION

A. Age of the respondents

The data placed in Table 1 reveals that majority of the respondents are middle aged (75.71%) followed by old aged (14.29%) and Young aged (10.00%). This trend indicates that the easiness of the technology might have attracted and facilitated the adoption of technology by middle aged farmers as they are more experienced.

B. Experience in drumseeder method of rice cultivation

The farmers were asked to inform their experience in terms of the number of years theywere cultivating rice using drumseeder method. It is observed from the Table 2 that about 71.00 per cent of the respondents have 1-2 years of experience in rice cultivation using drumseeder, while 14.00 per cent of the respondents have 3-4 years

Table 1. Age of the respondents (N=160)

Category	Frequency	Percentage
Young (Mean – SD)	16	10
Middle aged (Mean ± SD)	121	75.71
Old (Mean – SD)	23	14.29
Total	**160**	**100**

Mean = 40.2; S.D = 10.23

Table 2. Experience of respondents in direct seeding method using drumseeder (N=160)

Category	Frequency	Percentage
1 – 2 years	114	71
3 – 4 years	22	14
More than 5 years	24	15
Total	**160**	**100**

Mean = 2.5; S.D = 1.53

experience, and 15.00 per cent have more than five years experience in this method of rice cultivation. The data reveals that the respondents are very much satisfied with the technology and they are continuing the practice.

C. Continuation of the practice

It is observed from the Fig-2 that majority (95.7%) of the respondents are continuing the practice of direct seeding using drumseeder, while only a few of them (4.3%) have discontinued the practice. Factors that might have triggered the adoption of this practice continuously were technical feasibility, suitability to all types of soils, conduciveness to all categories of farmers and high net returns.

D. Perception of the respondents about the drumseeder method of rice cultivation

It is revealed from the Table – 3, that 100 per cent of the farmers felt that drumseeder method is an easy method of rice cultivation and it is suitable for any season round the year. All the respondents felt that the cost of cultivation is reduced in drumseeder method compared to traditional method as the requirement of labour is very much reduced. This might be due to skipping of operations like nursery

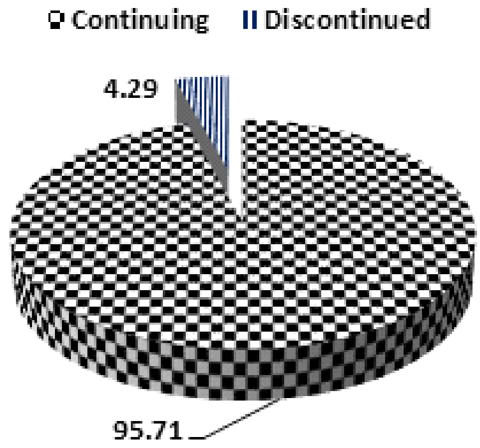

Fig. 2. Continuation/discontinuation of the drumseeder method of rice cultivation

rising, nursery pulling, transferring nursery to main field, manual transplanting in drumseeder method.

100 per cent of them felt that direct seeding in rice using drumseeder is feasible to all type of farmers compared to traditional and 'SRI' methods.

55.71 per cent of the respondents felt that weed management is difficult in drumseeder method, while 40 per cent felt that management of weeds is not a problem in this method of cultivation. A meagre 4.29 per cent of respondents could not decide and convincingly express the difficulty or easiness of the weed management practice. Since pre-germinated seeds are directly sown in drumseeder method, weeds emerge simultaneously with the main crop and compete for water and nutrients. Hence management of weeds using pre-emergence weedicides is compulsory in this method of cultivation. Exceptionally this may not be needed in the fields where weeds are not a big problem due to rigorous pre-crop land preparation activities prior to sowing the crop.

About 37.14 per cent of the respondents felt that the cost of weed management is high in direct seeded rice using drumseeder, while 61.43 per cent of the respondents didn't agree with this opinion. The probable reason might be continuous rains in the early days of sowing could have obstructed the application of pre-emergence weedicides or for any reason delay in timely application of weedicide reduced its effectiveness and hence engaged more labour for manual weeding.

With respect to water management practices, 35.71 per cent of respondents expressed that there is difficulty in management of irrigation water in drumseeder method, while 61.43 per cent stated that there is no difficulty in water management practice. A meagre 2.86 per cent are unable to express their view on this practice. Intermittent drying of the field upto panicle initiation stage is mandatory in drumseeder method and there after 2-5 cm water level is maintained in the field till 10 days before harvesting. In case of medium to heavy soils, this practice resulted in development of cracks resulting in inability to stand 2-5 cm of water level from panicle initiation stage. Moreover, farmers have to visit the field regularly to observe the moisture status and irrigate the field once in two days or three days depending on the texture of soil. Traditionally farmers are habituated to keep the field under water throughout the crop period and hence pay little attention in management of water.

About 67.14 percent of the respondents felt that irrigation water can be saved in drumseeder method compared to traditional rice cultivation method while 32.86 per cent didn't agree with this statement. Alternate wetting and drying the field upto panicle initiation stage and thereafter maintaining water level 2-5 cm till 10 days before harvesting is mandatory in drumseeder method and hence irrigating the field once for two days is sufficient, thereby saving power and water. Some farmers being afraid of the field cracks due to intermittent drying continued flooding the field from the day one to harvesting and hence they might have felt that there is no difference in water consumption between the drumseeder method and traditional method.

Cent per cent of the respondents expressed that the pest and disease infestation in drumseeder method is low compared to traditional method of rice cultivation. There is a spacing of 20 cms between rows and 5-8 cms between hills with rows have allowed plenty of sunshine and aeration to the plants and hence reduction in pest and disease infestation.

About 61.43 per cent of the respondents felt that fertilizer requirement is low in drumseeder method compared to traditional method while 38.57 per cent of respondents didn't agree with the statement. Running conoweeder between rows and usage of herbicides has reduced weed menace in the field thereby increasing the fertilizer use efficiency and hence the dosage of fertilizer requirement might have trimmed down. Few of the disagreed farmers have applied fertilizer doses similar to traditional system, while some have applied over and above the traditional dose as they observed heavy tillering in the crop.

All the respondents (100%) felt that the duration of the crop irrespective of the variety is reduced from 7-10 days in drumseeder method of rice cultivation. This could probably be due to avoidance of transplanting shock as the seeds are directly sown in the main field without transplanting operation.

Cent per cent of the respondents felt that the cost of cultivation is reduced in drumseeder method and net returns are more in this method compared to all other methods of rice cultivation. Operationally, the direct seeding with drumseeder method differs from traditional transplanting method in its operations for nursery raising, pulling the nursery, bundling the nursery, seed rate, transplanting, weeding and irrigation. The rest of the operations like fertilization, plant protection, harvesting, threshing, and bagging remain the same in both cases. This means that the direct seeding method is profitable for farmers even if they get normal regular yields. Over a period of five years, 5 – 50% higher yield is recorded in drumseeder method when compared to traditional transplanting method. Hence net returns are higher in drumseeder method compared to any other method of rice cultivation.

E. Suggestions for scaling up the drumseeder method of rice cultivation

When the respondents were asked to give suggestions for upscaling the drumseeder method of rice cultivation, 81.43 per cent of them expressed that the farmers who adopt drumseeder method should be supported by the Government in the form of incentives viz., inputs, subsidies etc. About 78.57 per cent of the respondents expressed that drumseeders should be made available with the farmers round the year. The same proportion (78.57%) of the respondents felt that a concrete solution for weed menace is essential for large scale adoption of drumseeder methodology. About 77.14 per cent of the respondents expressed that power weeders for weeding operation in drumseeder method are to be encouraged and promoted in a very big way.

Epilogue and policy implications

The results of the study on perception of respondents practicing drumseeder method reveal that the drumseeder method is the best method in terms of technical and

Table 3. Perception of respondents about drumseeder method of rice cultivation

S. No.	Particulars	Agree		Don't Know		Disagree	
		Freq	%	Freq	%	Freq	%
1	Drumseeder is an easy method of rice cultivation	160	100	0	0	0	0
2	Rice cultivation using Drumseeder can be done in any season	160	100	0	0	0	0
3	Cost of rice cultivation is reduced in drumseeder method	160	100	0	0	0	0
4	Requirement of labour is very much reduced in drumseeder method	160	100	0	0	0	0
5	Drumseeder method is feasible to farmers compared to traditional method and SRI method	160	100	0	0	0	0
6	Weed management is difficult in Drumseeder method	89	55.71	7	4.29	64	40
7	Cost of weed management is high in drumseeder method	59	37.14	2	1.43	98	61.43
8	Water management is difficult in drumseeder method	57	35.71	5	2.86	98	61.43
9	Irrigation water can be saved in drumseeder method compared to traditional method	107	67.14	0	0	53	32.86
10	Pest infestation is low in drumseeder method compared to traditional method	160	100	0	0	0	0.00
11	Fertilizer requirement is low in drumseeder method compared to traditional method	98	61.43	0	0	62	38.57
12	Duration of crop is reduced by 7-10 days in drumseeder method	160	100	0	0	0	0.00
13	Cost of cultivation is reduced in drumseeder method	160	100	0	0	0	0.00
14	Net returns are more in drumseeder method	160	100	0	0	0	0.00

Table 4. Suggestions given by respondents for upscaling the drumseeder method of rice cultivation

S. No.	Suggestions	Percentage*
1.	Drumseeders should be available with the farmers round the year	78.57
2.	Farmers adopting drumseeder method should be given incentives (subsidies, free inputs etc.,)	81.43
3.	Complete solution for weed menace is required	78.57
4.	Power weeders for weeding should be encouraged	77.14

* multiple responses

economic feasibility, low input requirement and reduced usage of hired labour and ultimately high net returns for the farmers. Most of the respondents are continuing and repeatedly practicing this method of rice cultivation. They expressed that drumseeder method is an easy method of cultivation and can be taken up in any season. The cost of cultivation is very much reduced compared to any other methods of rice cultivation as the labour requirement and drudgery is very much reduced. A few respondents felt that water and weed management is somewhat difficult and requires some skill on the part of farmer to do these operations efficiently. Low fertilizer requirement, low pest and disease infestation and low irrigation water requirement are the special features of this method of cultivation when compared to other methods of rice cultivation.Irrespective of the variety, the duration of the crop is reduced by 7-10 days in drumseeder method ensuring reduced irrigation water requirement, watch and ward problem and ultimately reduces physical and mental strain to the respondents.

The Policy makers and Researchers may consider the advantages of this method of cultivation and the speed of diffusion of this technology among the farming community. Groundwater is becoming more important within the rice sector as surface irrigation is facing a serious deceleration in spite of heavy investments in the sector. This drumseeder method has emerged as an alternative to traditional mode of flooded rice cultivation is showing great promise to address the problems of labour shortage, water scarcity, high energy usage and increased use of chemical fertilizers in field. Direct seeding using drumseeder is a viable option to reduce the exploitation of ground water resources for irrigation purpose and thus ensuring National Food Security mission through judicious use of natural resources.

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INFORMATION NEEDS AND INFORMATION SOURCES OF FARMERS OF PRAKASAM DISTRICT OF A.P.

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ABSTRACT

The present study was conducted in 5 villages of Prakasam Dist., with a sample size of one hundred and fifty farmers. Great majority of the framers expressed their information needs on new varieties in major crops (92.17%), new molecules for pest and disease management (81.33%) and pre emergence and post emergence herbicides in major crops (78.00%). Majority of the farmers preferred ADA/AO/AEO, bank officers, ANGRAU scientists and market committees as formal sources of information. Family members, neighbors, friends & relatives, progressive farmers and input agencies were the most preferred informal sources of information. Whereas Television and news paper were the most preferred mass media sources of information. With respect to constraints, over dependence on neighbors and input dealers for agricultural information, insufficient extension officers and non availability of need based information were the major constraints expressed by the respondents.

KEYWORDS: Constraints, Information needs and Information sources

INTRODUCTION

Information is a critical input for Agricultural Development which can be efficiently converted into economically rewarding opportunities. Information needs assessments give programme designers that ability to develop interventions that target users with specific information needs. In an information needs assessment, a farmer may highlight an important information need based on his/her requirement or interest, but unfelt or unrecognized needs will be revealed through his approach. Nevertheless, the value of an information needs assessments, by engaging directly with users of information, should not be over looked (Ali and Kumar, 2011). Knowledge about the information needs and information seeking behaviour of small-scale farmers is crucial to effectively satisfy their felt information needs and develop demand-led extension and advisory services (Garforth 2001). With relevant agricultural knowledge and information, farmers could improve their work in order to sustain agriculture and also benefit economically (Lesaoana-Tshabalala 2003).

Farmers use many different sources to obtain the knowledge and information they need to manage their farms well. Effective use of information sources for dissemination of information helps to reduce the time taken in the adoption process. Knowledge about the information sources would be helpful in developing a suitable extension strategy to uplift socio economic status of the farmers. Utilization of improved agricultural technology by the farmers, to a large extent, depends upon the effective sources of information and channels to which they are generally exposed directly or indirectly. But, to harness the potential for agricultural development, it is essential to understand the existing sources of information and their utility and relevance in terms of outreach, subject matter coverage and utilization by the farmers. Apart from identifying information needs and sources of agricultural information it is equally important to understand and analyze the constraints faced by the farmers in acquiring agricultural information. With this background the present study was designed to investigate the agricultural information needs of the farmers, information source preference and to analyze constraints expressed by the farmers.

MATERIAL AND METHODS

Five villages of Prakasam Dist. *Viz*., Dronadula, Bobbepalli, Bollapalli, Isukadarsi and Kolalapudi were selected randomly for conducting present study and accordingly gathered relevant information. An equal size of sample of 30 respondents each from these villages was drawn randomly to make the total size of 150 respondents. For collection of data, the interview was held personally

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at homes or the farms of the respondents in local dialect. The farmers were asked to list their information needs and constraints faced while acquiring agricultural information. The sources were placed into three groups i.e., formal, informal, and mass media. Each group was sub-divided into individual sources. To measure the extent use of information sources by the farmers, four point scale was used as 'regularly', 'occasionally', rarely' and 'never'. Finally, the collected data were analyzed using descriptive statistics (Frequency and percentage).

RESULTS AND DISCUSSION

Information needs of the farmers

Table 1shows the most common information needed by the farmers. The study revealed that great majority of the farmers (92.17%) said they needed information on new varieties with short duration, resistant to biotic constraints and drought in major crops of the district, followed by eighty one percent with an information need of new molecules for pest and disease management, pre and post herbicides in major crops (78.00%), insecticides, fungicides and herbicides compatibility (72.00%) and alternate crops to paddy (69.33). Whereas above half of the respondents expressed their need for information on micronutrient management (62.00%), biofertilizers use (58.66%), crop loans and crop insurance (58.00%). Nearly forty six percent expressed need for information on market forecast. Integrated pest management (54.67%) and Integrated disease management (52.67%). Almost forty five per cent had higher need for information on Phosphorus management, thirty eight per cent felt the need for organic farming, thirty seven percent sought for information on alternate crops to tobacco, thirty five per cent need information on management of problematic soils while thirty three percent needed information on water conservation methods and drought mitigation measures. Meitei and Devi (2009), in rural Manipur, found that farmers needed a variety of information related to seed varieties, pesticides and fertilizer. All these information needs expressed by the farmers were considered while planning training programs by the District Agricultural Advisory and Transfer of Technology Centre, Ongole.

Sources of information used by the farmers

Formal sources of information

It could be inferred from table 2 that almost fifty percent of the respondents used officers of Department of agriculture (ADA/AO/AEO) occasionally as a preferred source of information followed by forty three percent using bank officers as a good source of information. This is in agreement to the findings of Tologbonse and Adekunle, 2000; Tologbonse, 2002 and Tiamiyu, *et.al*. (2009), that extension agents are important sources of agricultural information. Whereas thirty eight percent of farmers were using Kisan Call Centers to get agricultural information regularly and same percent of respondents were using market committees occasionally to get market information. Forty percent of the respondents expressed ANGRAU scientists as their preferred source occasionally for technical knowhow. However, great majority of the farmers never used school teachers (98.00%), NGOs (96.00%), gram sarpanch (94.00%), ICAR scientists (90.00%), State level call centre (72.00%) and Cooperatives (50.00%) as a source of information.

Informal sources of information

The results given in table 3 are clearly depicting that 'family members' as a source of information proved to be the most important as it has been preferred by great majority (74.00%) of the respondents as a good source of information. Similarly, neighbors, progressive farmers, relatives and friends were preferred and used regularly by the farmers under personal localite sources of information. The trend where farmers relied on friends, neighbors and farmers' colleagues were also observed by Okwu and Dauda (2011), Achugbe and Anie (2011) and Rezvanfar *et. al*. (2007) indicating the strong social dynamics of 'across the fence' contact when in need or facing challenges. The ease or proximity of the source could also be an enabling factor here. Meanwhile, the findings indicate the importance of farmer-to-farmer extension model in technology dissemination.

Obviously, it can be said that input agencies and neighbors were occasionally preferred informal sources. Therefore, it is suggested that these information sources should be made use of by the extension agents in effective diffusion of technical know-how among the farmers. In addition, attempts should also be made to keep in view the preference expressed by the respondents for use of different sources while making use of these sources for dissemination of the knowledge among the farmers. Cent percent of the farmers never approached agri clinics for information; this may be because of non existence of agri clinics in the study area.

Table 1. Information needs of the farmers

N = 150

S. No.	Information needs	Frequency	Percentage
1	New varieties in major crops of the district	139	92.17
2	New molecules for pest and disease management	122	81.33
3	Pre emergence and post emergence herbicides in major crops	117	78.00
4	Insecticides, fungicides and herbicides compatibility	108	72.00
5	Alternate crops to paddy	104	69.33
6	Micronutrient management	93	62.00
7	Biofertilizers use	88	58.66
8	Crop loans and crop insurance	87	58.00
9	Integrated pest management	82	54.67
10	Integrated disease management	79	52.67
11	Market forcast	70	46.67
12	'P' fertilizer management	67	44.67
13	Organic farming	57	38.00
14	Alternate crops to tobacco	56	37.33
15	Management of problematic soils	53	35.33
16	Water conservation and drought mitigation methods	49	32.67

Mass Media sources of information

From table 4 it could be inferred that great majority of the farmers said television (94.00%), followed by news paper (92.00%) were the major mass media sources referred by them regularly to acquire agricultural information. Cent percent of the farmers never referred information kiosk as a source of information. This may be because of lack of awareness among the farmers about information kiosk. Almost seventy percent (68.00%) of the farmers never used information bulletins. Above half of the respondents never preferred radio as an information source. Nearly fifty percent of the farmers never preferred journals and university publications for getting agricultural information. Forty six percent of the farmers were never using film shows. On the other hand some of the farmers were using journals (22.00%), magazines and university publications (20.00%) occasionally.

Constraints expressed by the farmers

It is evident from Table 5, almost three fourth (74.00%) of the farmers expressed over dependence on neighbors and input dealers for agriculture information is their major constraint which ultimately leading indiscriminate and excess use of agricultural inputs resulting in increased cost of cultivation and poor net returns. This is because majority of the farmers prefer neighbors, relatives, input dealers as a source of information due to their local availability. Almost seventy one percent of the farmers expressed insufficient number of extension officers as their constraint. The probable reason for this may be large area to be covered by the Mandal Agricltural Officer and large number of schemes to be implemented by them. Non availability of need based information is another constraint expressed by 64.67 per cent farmers. Above fifty percent of the farmers expressed

Table 2. Extent use of Formal sources of information by the farmers

N = 150

S. No.	Information source	Extent of use							
		Regularly		Occasionally		Rarely		Never	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1	ADA/AO/AEO	9	6.0	72	48.00	54	36.00	15	10.00
2	Gram sarpanch	0	0.0	3	2.00	6	4.00	141	94.00
3	Bank officers	0	0.0	65	43.33	46	30.67	39	26.00
4	ANGRAU scientists	24	16.00	60	40.00	39	26.00	27	18.00
5	ICAR scientists	0	0.0	3	2.00	12	8.00	135	90.00
6	Cooperatives	0	0.0	30	20.00	45	30.00	75	50.00
7	Market committees	0	0.0	57	38.00	24	16.00	69	46.00
8	School teachers	0	0.0	0	0.00	3	2.0	147	98.00
9	NGOs	0	0.0	0	0.00	6	4.0	144	96.00
10	Call centre								
a	Kisan call centre	57	38.00	30	20.00	24	16.00	39	26.00
b	State level call centre	0	0.00	30	20.00	12	8.00	108	72.00

Table 3. Extent use of Informal sources of information by the farmers

N = 150

S. No	Information source	Extent of use							
		Regularly		Occasionally		Rarely		Never	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1	Family members	111	74.00	27	18.00	12	8.00	0	0.0
2	Neighbours	81	54.00	63	42.00	6	4.00	0	0.0
3	Friends & relatives	75	50.00	36	24.00	24	16.00	15	10.00
4	Progressive farmers	81	54.00	45	30.00	0	0.0	24	16.00
5	Input agencies	3	2.0	87	58.00	6	4.00	54	36.00
6	Agri clinics	0	0.0	0	0.0	0	0.0	150	100.00

Table 4. Extent use of Mass media information sources by the farmers

N = 150

S. No.	Information source	Extent of use							
		Regularly		Occassionally		Rarely		Never	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1	News paper	138	92.00	9	6.00	0	0.0	3	2.00
2	Magazines	54	36.00	30	20.00	18	12.00	48	32.00
3	University publications	36	24.00	30	20.00	12	8.00	72	48.00
4	Information bulletins	21	14.00	12	8.00	15	10.00	102	68.00
5	Journals	39	26.00	33	22.00	6	4.00	72	48.00
6	Radio	15	10.00	24	16.00	30	20.00	81	54.00
7	Television	141	94.00	3	2.00	3	2.00	3	2.00
8	Film shows	45	30.00	15	10.00	21	14.00	69	46.00
9	Information kiosk	0	0.0	0	0.0	0	0.0	150	100.00
10	Internet	0	0.0	3	2.00	9	6.00	138	92.00

Table 5. Constraints expressed by the farmers in acquiring information

N = 150

S. No.	Constraints	Frequency	Percentage
1	Over dependence on neighbors and input dealers for agriculture information	111	74.00
2	Insufficient extension officers	106	70.67
3	Non availability of need based information	99	66.00
4	Non accessibility of personal cosmopolite sources	97	64.67
5	Non availability of reliable information sources locally	89	59.33
6	Untimely visits of Dept. of Agriculture visits	85	56.67
7	Illiteracy	69	46.00
8	Mass media programs are not location specific	67	44.67
9	Lack of awareness on information sources	61	40.67
10	Complexity of the information given through mass media	52	34.67

that non availability of reliable information sources locally (59.33%), untimely visits of Dept. of Agriculture officers (56.67%). Illiteracy was also one of the constraints perceived by almost half of the respondents (46.00%). Below half of the respondents perceived that mass media programmes are not location specific (44.67%), lack of awareness on information sources (40.67%) and complexity of the information given through mass media (34.67%) as their constraints in getting agricultural information.

CONCLUSION

Access to adequate, relevant and reliable agricultural information is an essential factor towards building a strong and virile agricultural foundation. Therefore, how far people progress in whatever they are doing in agriculture depends largely upon the availability and access to accurate and reliable information. An effective extension strategy should be designed with the farmer's information needs and their preferred sources of information in mind. This would reduce the number of sources of information the farmer needed to access, reducing the time and effort the farmer had to spend on information seeking and potentially hastening the adoption decision.

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THE MITSCHERLICH PLANT GROWTH MODEL FOR DETERMINING THE DTPA EXTRACTABLE COPPER IN SOIL

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ABSTRACT

A mathematical model, based on the first order rate equation derived to determine the critical nutrient level in soil and plants. The model has been used to determine the critical level by characterizing plant growth as a function of nutrient concentration in plant tissues or content of the soil. A field experiments was conducted to establish critical limit to DTPA extractable Cu with graded levels of Cu (0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 kg Cu ha^{-1}) as adopted during 2012-13 for onion growing soils in Tamil Nadu. The curve linear equation was developed based on the Bray's percentage yield (Y) and soil available Cu (x). The extrapolated Bray's per cent yield values at varying definite interval (0.1 mg kg^{-1}) of DTPA extractable Cu in the soil were determined from the equation. The estimated Bray's per cent yield was started to decline after the increasing the DTPA level of 3.00 mg kg^{-1} and upto this extrapolated Bray's percentage yield was considered for estimation of ã. The critical concentration of available Cu in soil worked out to be 0.625 mg kg^{-1} below which appreciable responses to Cu application was expectable.

KEYWORDS: DTPA extractable Cu, Mitscherlich method, Onion growing soils, Onion leaf, Plant growth model.

INTRODUCTION

Copper is an essential micronutrient for normal growth and metabolism of plants (Sharma and Agarwal 2005; Singh *et al*. 2007). Onion belongs to a group of vegetables that have high response to Cu (Swiader and Ware 2002). Micronutrient deficiencies become a major constraint for crop productivity in many Indian soils. The deficiency of micronutrients may either be primary, due to their low total contents or secondary, caused by soil factors that reduce their availability to plants (Sharma and Chaudhary 2007). Knowledge of micronutrient availability in the soil is fundamental for suitable fertilizer recommendations, to avoid deficiency or toxicity problems. Several studies have been conducted to determine the critical nutrient level in soils and plants. The critical levels have been determined by relating available nutrient content of the soil or nutrient concentration in the crop plant with yield. The critical limit in plant refers to a level at or below which plant either develops deficiency symptoms or causes statistically significant or 5 to 10 percent reduction in crop yield as compared to optimum (Debnath and Ghosh 2012).

Clear prediction of deficiencies, critical limits must be refined with reference to nutrient levels both in soil and plant. The suitable fertilizer recommendation can be presented by calibration experiments with crop response results for each crop and determining of critical level of the element is necessary for particular crop (Soltanpour *et al*., 1986). Therefore, it is desirable to precisely know the critical limit of micronutrient in soil and plant is highly useful for providing suitable micronutrient application for crops. It reduces the concentration of micronutrients in soil solution below that required for normal growth. A modified Mistscherlich response equation to quantify critical deficiency levels by characterising plant growth as a function of tissue nutrient concentration (Ware *et al.,* 1982). Critical level of Cu was reported as 1.3 mg kg^{-1} by Mistcherlich-Bray equation for obtaining 80 percent of maximum grain yield in wheat (Feiziasl *et al.,* 2009). Sharma (1991) found that the critical N concentration of 3rd leaf from top of the potato for getting optimum tuber yield. Hence the present investigation was undertaken to study the response of onion to Cu fertilisation in the field conditions and to determination of critical limit the DTPA extractable Cu in soils

MATERIAL AND METHODS

Field experiments were conducted at eight locations in various farmer fields at Vadivellampalayam, Panaiyampalli and Pungampalli villages in Tamil Nadu during *Rabi* season (2012-13) for refinement of Copper

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critical limit in soils.The soil of the experimental fields were belonging to the soil series Irugur, Manupatti, Vellalur, Palathurai, Athipalayam, Kanjampatti, Sommaiyanur, Puduvadavalli and Annur soil series (Table 1). The initial analysis of experimental soil was neutral to slightly alkaline in reaction and free from salts. The organic carbon content of the soil was low. The soil was low in available N and P, medium in available K, sufficient in DTPA extractable Zn, Mn, Fe and hot water soluble boron. Based on the available status of Cu, eight farm holdings (L1 to L8) were selected (on the ascending order of Cu status stating from 0.22 mg kg^{-1} at interval of 0.2 mg kg^{-1}). The experiment was laid out in a randomised block design replicated thrice with seven levels of Cu application *viz*., 0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 kg ha^{-1} along with recommended fertiliser dosage 60:60:30 kg N, P_2O_5 and K_2O kg ha^{-1} (Table 2). The fertilizers were applied in the form of urea, super phosphate and muriate of potash to all the treatments. Before sowing of onion bulbs, the required quantity of Cu was applied through $CuSO_4$ as per the schedule. After harvesting of crop weight of bulbs was recorded separately and the collected soil samples were processed and analyzed for DTPA extractable copper with help of atomic absorption spectrophotometer.

A mathematical model, based on the first order rate equation was derived to determine the critical nutrient levels in soil and plants. The model has been used to determine nutrient levels by characterizing plant growth as a function of nutrient concentration in plants or nutrient available in soil or nutrient applied. The critical nutrient level can be determined by the equation $x = -\text{In}\,(0.1/Y) / K$,where

$$K=\sum_{k=1}^{1-n}\left(\frac{2.303}{x}\ \log 10\ \frac{a}{a-y}\right)n-1 \text{ and } Y=\left(\frac{a-y_0}{a}\right)$$

where,

a = maximum estimated yield;

y_0 = minimum estimated yield (Sharma 1991).

RESULT AND DISCUSSION

A mathematical model, based on the first order rate equation derived to determine the critical nutrient level in soil and plants. The model has been used to determine the critical level by characterizing plant growth as a function of nutrient concentration in plant tissues or content of the soil. The model determines the critical soil nutrient level for which a large body of data is desired in order to get accurate critical values. The curve linear equation was developed based on the Bray's percentage yield (Y) and soil available Cu status (x). The extrapolated Bray's per cent yield values at varying definite interval of DTPA extractable Cu in the soil were determined from the equation.

$$Y = 34.07 + 14.39\,x - 2.419\,x^2.$$

The extrapolated Bray's per cent yield values at varying definite interval (0.1 mg kg^{-1}) of DTPA extractable Cu in the soil was determined from the equation (Table 3).The estimated Bray's per cent yield was start to decline after the increasing the DTPA level of 3.00 mg kg^{-1} and up to this the extrapolated Bray's percentage yield was considered for estimation of γ, *i.e.* ratio of difference between maximum and minimum extrapolated yield divided by maximum yield.

γ = (55.50-34.07) / 55.50

γ = 0.3860

The average K value is 2.160.

Critical limit (x) = -In (0.1/γ) / K

x = 0.6253

The critical limit of DTPA extractable soil Cu value obtained from this study is 0.625 mg kg^{-1}. Using the Mathematical method 0.625 mg kg^{-1} is the critical limit of DTPA extractable Cu in onion growing soils. Sharma (1991) reported the critical limit of 0.75 mg kg^{-1} DTPA-Zn for potato grown soil and also found that the critical N concentration of 3rd leaf from top of the Potato for getting optimum tuber yield. Similarly, Ware *et al*., (1982) used a modified Mitscherlich response equation to quantify critical deficiency levels characterizing plant growth as a function of tissue nutrient concentration.

CONCLUSIONS

A mathematical model, based on the first order rate equation derived to determine the critical nutrient level in soil and plants. The model has been used to determine the critical level by characterizing plant growth as a function of nutrient concentration in plant tissues or content of the soil. The curve linear equation was developed based on the Bray's percentage yield (Y) and

Table 1. Physical and chemical properties of the experimental site

S. No.	Particulars	Values							
		Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Field 7	Field 8
I.	**Physical properties**								
1	Sand (%)	78.13	68.3	73.36	52.4	70.52	67.69	45.1	57.8
2	Silt (%)	2.55	13.9	8.12	22.2	7.60	8.11	16.2	15.5
3	Clay (%)	19.32	17.8	18.52	25.4	21.88	24.20	38.70	26.70
4	Textural Class (%)	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Clay loam	Clay loam
	Soil Series	Manupatti	Kanjampatti	Annur	Irugur	Puduvadavalli	Kuppandampalayam	Palathurai	Vellalur
II.	**Physico-Chemical properties**								
1	Soil pH	7.65	7.53	7.32	7.43	7.72	7.31	7.71	7.74
2	EC (d S m^{-1})	0.28	0.41	0.32	0.52	0.43	0.27	0.53	0.37
3	Organic carbon (g kg^{-1})	0.47	0.45	0.4	0.43	0.24	0.33	0.43	0.33
4	CEC (c mol(p+)kg^{-1})	15.2	17.8	19.4	22.3	17.0	28.8	22.9	24.5
III.	**Chemical properties**								
1.	Available N (kg ha^{-1})	268	252	261	236	262	268	270	267
2	Available P (kg ha^{-1})	9.4	8.8	9.9	14.4	10.8	9.8	11.0	11.1
3	Available K (kg ha^{-1})	359	291	273	257	432	261	379	206
4	Available Fe (mg kg^{-1})	8.89	10.94	5.41	7.81	5.59	6.55	8.96	9.99
5	Available Zn (mg kg^{-1})	1.38	1.38	1.40	1.44	1.25	1.36	1.38	1.33
6	Available Mn (mg kg^{-1})	5.15	7.50	3.56	4.22	4.94	3.55	6.33	5.33
7	Available Cu (mg kg^{-1})	0.22	0.42	0.62	0.82	1.04	1.23	1.42	1.63

Table 3. Estimation of rate of constant (K) in the onion crop experiments

S. No.	$Y = 34.07 + 14.39 x - 2.419 x^2$		
	DTPA-Cu (mg kg^{-1})	Estimated Bray's Per cent yield	K value
1	0.00	34.07	0.00
2	0.10	35.49	9.52
3	0.20	36.86	5.10
4	0.30	38.18	3.64
5	0.40	39.45	2.91
6	0.50	40.67	2.48
7	0.60	41.84	2.20
8	0.70	42.97	2.00
9	0.80	44.05	1.86
10	0.90	45.07	1.75
11	1.00	46.06	1.67
12	1.10	46.99	1.61
13	1.20	47.87	1.56
14	1.30	48.71	1.53
15	1.40	49.49	1.50
16	1.50	50.23	1.48
17	1.60	50.92	1.47
18	1.70	51.56	1.47
19	1.80	52.16	1.47
20	1.90	52.70	1.48
21	2.00	53.20	1.49
22	2.10	53.65	1.52
23	2.20	54.04	1.54
24	2.30	54.40	1.58
25	2.40	54.70	1.63
26	2.50	54.95	1.70
27	2.60	55.16	1.78
28	2.70	55.32	1.89
29	2.80	55.43	2.04
30	2.90	55.49	2.28
31	3.00	55.50	2.80
32	3.10	55.47	
33	3.20	55.38	

Table 2. Treatment details

T. No.	Treatments
1.	Control (Recommended dose of NPK fertiliser alone)
2.	T1 + 0.5 kg Cu ha^{-1}
3.	T1 + 1.0 kg Cu ha^{-1}
4.	T1 + 1.5 kg Cu ha^{-1}
5.	T1 + 2.0 kg Cu ha^{-1}
6.	T1 + 2.5 kg Cu ha^{-1}
7.	T1 + 3.0 kg Cu ha^{-1}

soil available Cu (x). The extrapolated Bray's per cent yield values at varying definite interval (0.1 mg kg^{-1}) of DTPA extractable Cu in the soil were determined from the equation. The estimated Bray's per cent yield was started to decline after the increasing the DTPA level of 3.00 mg kg^{-1} and upto this extrapolated Bray's percentage yield was considered for estimation of ã. The critical concentration of available Cu in soil worked out to be 0.625 mg kg^{-1} below which appreciable responses to Cu application was expectable.

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