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RAPD AND SCAR MARKER FOR DETERMINATION OF SEX IN SIMAROUBA (*Simarouba glauca*) FOR IMPROVED PRODUCTION

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ABSTRACT

A total of 250 random oligonucleotide primers were surveyed to identify sex of *Simarouba glauca,* a tree born oilseed crop. Primer OPA-08 produced a consistent marker, differentiating female from male and andromonoecious sex plants. An identified random amplified polymorphic DNA (RAPD) marker, OPA-08, linked to male sex in Simarouba was cloned and sequenced. Their end sequences were used to design an allele-specific sequence characterized amplicon region (SCAR) primer SCAR (12f/r), which was promising in male and andromonoecious sex. The marker designed was amplified at a specific site of 915 bp only in male and andromonoecious plants. This would help to identify the sex of tree born oilseed crop Simarouba.

Simarouba glauca is a tree born oilseed crop. It belongs to the family Simaroubaceae and is a native of El Salvador (Central America). The seeds of Simarouba are economically very important since they contain 55-60% edible oil (Armour, 1959). As demand for edible oil is steadily increasing and production being stagnated it is inevitable to resort to the tree born oilseed crop which can be successfully grown in the available non arable lands. Simarouba, the oil tree is one such ideal evergreen versatile crop which can grow even in waste lands. It is being cultivated in Bihar, Orissa, Gujarat, Rajasthan, Karnataka, Tamilnadu and Andhra Pradesh etc.

Simarouba is polygamodioecious with three types of plants (Fig.1, 2, 3) namely pistillate (Female flowers), Staminate (Male flowers) and andromonoecious (male dominated bisexual flowers) (Joshi and Hiremath, 2000). Flowering is annual, beginning in December and continuing up to next February and bears fruits during March –April and fruits can be collected in the month of May. The inflorescence is a compound panicle with main axis showing racemose pattern and ultimate branches having dichasial/ monochasial cymes. The time taken from bud initiation to anthesis is about 15 days. The male inflorescence has a longer peduncle than the female. The length of the panicle is 20-45 cm in pistillate whereas it is 50-60 cm in andromonoecious and staminate inflorescences. The bisexual flowers form 0.5-5% of the total flowers in an andromonoecious panicle. Bisexual flowers are the largest with 12-15mm diameter followed by male flowers with 9-12 mm diameter and the female flowers are the smallest with 6-8 mm diameter.

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The male inflorescence bear maximum of 2500-6250 flowers, the andromonoecious will have 1200-5500 flowers and the female bear 200-650 flowers (Fig.4). In male and bisexual flowers, androecium has 10 stamens in two whorls. In female flowers the androecium is represented by 10 staminodes (sterile stamens) with poorly developed anthers not producing any pollen grains. The pollen is creamy and light, easily carried by wind and insects for pollination.

Simarouba usually flowers after 3-4 years after planting .The waiting time from sowing to flowering is long, hence growers need to ensure that a seedling is a female for good harvest.The determination of the sex of Simarouba seedling prior to the flowering stage would avoid the need for removing undesired sex types from the field as only five percent male or andromonoecious plants in a field are sufficient for pollination.By cultivating male and female plants, planting space, fertilizers and water could be optimized. However, they cannot be distinguished at the seedling and vegetative stages of growth. Identification of sex types prior to propagation, especially in polygamodioecious plant species with a long juvenile cycle such as Simarouba, would result in higher fruit production and increased profitability. Molecular markers like ISSR and RAPD markers were developed by Deputy *et al.,* (2002) and Gangopadhyay *et al.,* (2007) to determine sex in papaya in pre flowering stage. Similar studies were initiated to determine sex at seedling stage in Simarouba for improved yield and RAPD method was successfully developed to identify the gene related to sex of the plant.

MATERIALS AND METHODS

The leaf material of *Simarouba glauca* was collected from the trees of 5 years old grown at Forest Research Station, Kukkaladoddi, Tirupati Division, Andhra Pradesh.

DNA extraction: Tender and fresh leaf samples of 32 male and 27 female known plants were collected and DNA was extracted using CTAB method (Sambrook *et al.,* 1989). 400 mg of leaves were completely homogenized with liquid nitrogen. Extraction buffer(100 mM Tris HCl (pH 8.0), 20 mM EDTA, 1.4 M NaCl, 3% CTAB, 1% PVP, 1% â-mercaptoethanol was added in 2 ml eppendorff tubes filled with leaf powder to the volume 1.5 ml and mixed well. The tubes were incubated at 65°C for 1/2 h with repeated shaking. Equal volume of chloroform : isoamyl alcohol mix(24:1) was added and mixed thoroughly followed by centrifugation at 10000 rpm for 10 minutes at room temperature. Supernatant was transferred to another sterile 2 ml eppendorff tube and chloroform: isoamyl alcohol step was repeated until a clear supernatant was obtained. 5 M NaCl (0.5v/v) was added and mixed gently followed by addition of 0.8 volume of ice cold isopropanol to the aqueous layer and incubated overnight at -20°C. The content was centrifuged at 13000 rpm for 20 minutes at 4ºC and supernatant was discarded.

The pellet was washed with 70% ethanol and air dried. Then the pellet was dissolved in 200 µl of TE/distilled water. The DNA was incubated with 10 mg/ml of RNase for 1 h at 37°C. To this equal volume of phenol: chloroform (25:24) was added and centrifuged at 1000 rpm for 10 minutes at room temperature. This step was repeated thrice followed by washing with an equal volume of chloroform: isoamyl alcohol twice. DNA was precipitated with 0.1 volume of 3M sodium acetate and twice the volume of ice cold ethanol at -20°C for one hour. The resultant pellet obtained after centrifugation was washed with 70% ethanol, air dried and dissolved in 50 µL of TE/ distilled water. The quality and quantity of DNA were checked through 1% agarose gel by electrophoresis. The DNA obtained was quantified using Nanodrop spectrophotometer.

RAPD analysis:

Genomic DNA was used as template for PCR amplification as described by Williams *et al*., (1990). Amplification was carried out with 25 µL reaction volume containing 1X Assay buffer, 1.5 mM Mg Cl_2, 0.2 mM dNTP, 5 pmoles primer (Operon Technologies Inc.), 25-30 ng of genomic DNA and 1 unit of Taq DNA polymerase. Amplification was performed in 0.2 ml thin walled tubes using a thermocycler (Corbett, Australia) programmed for initial denaturation at 94 ºC for 5 minutes, followed by 45 cycles of denaturation at 92 ºC for 1 minute, annealing at 35 ºC for 2 minutes, primer extension at 72 ºC for 2 minutes and a final extension at 72 ºC for 10 minutes .PCR amplified products were subjected to electrophoresis on 1% agarose gel in TBE buffer. The electronic image of ethidium bromide stained gels were captured using Alpha imager system.

Cloning and sequencing of RAPD markers

RAPD primer OPA-08 (Operon Technologies Inc., Alameda, CF, USA) was used to amplify genomic DNA of male Simarouba plant. Amplified fragments were separated on a 1% (w/v) low melting point agarose gel before being excised and purified by means of the QIAquick Gel Extration Kit (Qiagen, Valencia, CA, USA). The purified DNA fragments were ligated and transformed with the pTZ57R/T Easy Vector System. Cloned RAPD fragments were identified via Colony PCR with RAPD primer of OPA-08 and confirmed by restriction digestion with *Eco*RI (Fig. 6).

SCAR primer design and amplification

On the basis of the sequence of cloned RAPD product, oligonucleotide primer pairs of 12 and 14 bases were designed using Oligo Explorer 2.0 software for specific amplification of the loci identified by selected RAPD marker. Each primer contained the original 10 bases of the RAPD primer sequence plus the next 2 and 4 internal bases **(**Table 1). Care was taken

to avoid possible primer dimer or secondary structure formation. Primers were synthesized by Operon Technologies, Inc. SCAR amplification of female, male and andromonoecious genomic DNA was performed in 25 µL reaction volumes containing the same components used for RAPD analysis. PCR amplification consisted of 35 cycles of 1 minute at 92 °C, 1 minute at 51 °C, and 2 minute at 72 °C followed by a final extension of 10 minute at 72 °C. Agarose electrophoresis was performed as described for RAPD analysis.

RESULTS AND DISCUSSION

About 250 random primers were screened to select marker showing good amplifications which were further used to identify regions associated with sex linked marker. Specific amplification with 900bp band in males and andromonoecious (male dominated bisexual flowers) was produced by OPA 8 (Fig.5). Reproducibility of the primer was tested by repeating the PCR amplification thrice under similar conditions. The amplified products were separated on 1% agarose gel and were analyzed by comparing them with 1Kb DNA ladder. From the sequence of 915bp, two SCAR primers were designed with 12, and 14 bp (Table-1). SCAR 12f/r with consistent results was utilized in screening of all simarouba lines (Fig 7) and gave specific band at 915bp in males and andromonoecious plants only

A major problem associated with RAPD technology is the reproducibility of the profiles and it has been the subject of considerable debate among various investigators (Melotto, *et al* 1996 Zhag and Stommet, 2001). To ameliorate the utility of RAPDs, SCARs that have greater reliability than simple RAPDs were developed. SCARs have several advantages over RAPD markers in marker assisted selection. Because more stringent reaction conditions are used, SCAR markers are generally more allele specific and SCAR amplifications are more stable and reliable and more easily reproduced in different laboratories with various thermal cycles. Thus OPA-08 was converted to a SCAR for increasing reproducibility. This may help in detection of sex at seedling stage. SCAR developed from RAPD markers have the advantages of cost effectiveness and technical simplicity.

The RAPD marker in this study converted into simple SCAR marker SCAR12f/r for large-scale application in marker- assisted breeding. This involves the characterization of the linked maker and the design of locus-specific primers. The conversion of a linked marker to SCAR has been applied successfully in a number of crops, like common bean (Melotto, *et al* 1996), rice (Naqvi, *et al* 1996) and tomato (Zhag and Stommet, 2001).

The PCR based markers for sex prediction in Simarouba have the advantage that they are not affected by environmental conditions in which the plants are grown or by epistatis (gene interaction) Thus, sex prediction can be done at any development stage of plant growth.. Knowledge of the sex of Simarouba is important in selecting parents for use in hybridization

work. In addition for micro propagation, the early detection or identification of the sex type of a particular seedling would be advantageous, since the desired sex type can be selected prior to micro propagation. This will ensure that the resulting micro propagated plants are 100% female.

Table 1. SCAR Primers designed based on the sequence of RAPD marker and the size of amplicon observed

S.No	Primer	Primer sequence (5' – 3')	Length (mer)	Annealing temp.(°C)	Size (bp)
1.	SCAR1- F	GTG ACG TAG GTA TGG	15	50	91
2.	SCAR1 - R	GTG ACG TAG GGA GA	14		
3.	SCAR2 - F	GTG ACG TAG GTA	12	51	915
4.	SCAR2 - R	GTG ACG TAG GGA	12		

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ROLE OF MEDICINAL PLANTS IN TRADITIONAL HEALTH CARE SYSTEM: A CASE STUDY FROM NALLAMALAIS

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ABSTRACT

The Nallamalais is a group of moderately steep hills in the central part of the Eastern Ghats. These ranges have typical gorges and gaps due to faulting the stream erosion resulting into a discontinuous range. The study area of the forest is of moist deciduous and dry deciduous mixed type with patches of scrub forest. The dominant tree species are *Anogeissus latifolia, Boswellia serrata, Chloroxylon swietenia, Dalbergia paniculata, Hardwickia binata, Pterocarpus marsupium* and *Terminalia alata.* Nallamalais was explored to inventory sampling in study site areas by laying a quadrate of 10x10 m., 5x5 m.and 1x1 m. All the plant species encountered in quadrats were listed. A total of 324 species belonging to 252 genera and 96 families were recorded. Out of which 116 tree species of 40 families, 167 herbaceous species of 37 families and 41 shrub species of 19 families listed. Of these only 66 species are used to cure only 5 listed major diseases i.e. Asthma, cardiac, diabetes, snake bite, scorpion sting.

Man believed that medicinal plants help to re-harmonise the diseased body itself with its environment. Many traditional societies all over the world value a large number of plant species from the wild for a variety of reasons, for food, fibre, shelter or medicine. The basic elements of nature in the form of *Prithvi* (Earth), *Agni* (Fire), *Jal* (Water), *Vayu* (Air) and *Akash* (Space) were always worshipped or revered in one or the other form from the ancient times as per the Hindu mythology for curing their diseases. These elements of nature were visible god and as a result, got protection for spiritual, religious cultural and social reasons. There are 72,000 plant species being used in various human cultures around the world for medicinal purposes (Schipmann *et al.,* 2006). Out of which, 17,000 flowering plants reported from India and 8000 plants are used in various systems of Indian medicine (Ayurveda 2351, Siddha 1785, Homeo 506 and Unani 979). The active principles found in medicinal plants are alkaloids, glycosides, tannins, flavonoides or other similar compounds of a very complex nature. They are found in root, bark, stem, leaf, fruit and seed (Anonymous, 2003-2005 and Bahadur *et al*., 2007). About 70-80% of the rural population in many tropical developing countries still depend on traditional medicine for their primary health care, which also means that the people have to depend on medicinal plants for treatment (Farnsworth *et al*., 1985). India is the seventh largest and one of the 12 mega biodiversity countries in the

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world covering wide diversity in environmental and bio-geographical conditions which lead to the development of a wide range of vegetation types (Champion and Seth, 1968) and represents a very rich flora including a large number of endemic species.

STUDY AREA

The Nallamalais is a group of moderately steep hills in the central part of the Eastern Ghats between latitudes 15°20' – 16°30' N and longitudes 78°30' - 80°10' E in Kurnool, Mahboobnagar, Prakasam, Guntur and Nalgonda districts of Andhra Pradesh. These ranges have typical gorges and gaps due to faulting stream erosion resulting into a discontinuous range. The altitude varies from 300 to 800 m above MSL and most of the peaks are above 650 m above MSL. The study area in the forest is of moist deciduous and dry deciduous mixed types with patches of scrub forest. The dominant tree species are *Anogeissus latifolia* L. (Combretaceae), *Boswellia serrata* Roxb. ex Colebr. (Burseraceae), *Chloroxylon swietenia* DC. (Rutaceae), *Dalbergia paniculata* Roxb. (Fabaceae), *Hardwickia binata* Roxb. (Fabaceae), *Pterocarpus marsupium* Roxb. (Fabaceae) and *Terminalia alata* Hyene ex Roth (Combretaceae).

The Nallamalais is one of the centres of plant diversity (CPD) and is spread over 6740 km^2. The WWF-IUCN identified 13 centres of plant diversity in India including Nallamalais (WWF-IUCN, 1995). The hills cluster near Gundlabrahmeswaram is the nucleus of the Nallamalais appearing as plateau. It is a dry ecological region of peninsular India and the hot period between March and May with the temperature reaching up to 45°C. The average annual rainfall is 740 mm.

PROTECTED AREAS

There are two wildlife sanctuaries namely Nagarjuna Sagar – Srisailam and Gundlabrahmeswaram in the district mainly for the tiger conservation (Fig. 1). Nagarjuna Sagar, Srisailam Tiger Project (Wildlife) with area of 3,568 km^2, covering five districts i.e., Kurnool, Mahaboobnagar, Prakasam, Nalgonda and Guntur lies between 15° 53'N – 16° 43'N and 78° 30'E – 79 28E. Gundlabrahmeswaram with an area 1,194 km^2 covering Kurnool and Prakasam districts lies between 15° 40'N – 15° 89'N and 78° 06'E – 78° 09'E. Out of the 8 medicinal plant conservation centers established by the State Forest Department, 1 in Pedda cheruvu area of 220 ha, is located in Nallamalais.

ETHNOLOGY

Out of 54 tribals inhabiting the Eastern Ghats, 33 groups of tribes belong to Andhra Pradesh. Chenchus and non-aboriginal and migrated Lambadies, migrated Yerukala and Yanadi in Nallamalais are the most primitive tribes. The Chenchus is an aboriginal and

oldest tribe of South India. The total population in Nallamalais is about 39,000 representing 10,000 families in five districts and 50% of them are confined to Mahboobnagar, Kurnool and Prakasam districts (Census 2001). The communities living in and around the forest areas especially the core tribal Chenchu groups are dependent on these resources for their basic lively hood i.e., food, medicine, and other needs. The tribal populations are endowed with rich traditional knowledge and information on the use of medicinal plants.

MATERIALS AND METHODS

The present study was carried out during 2007-2009 as part of research work on quantitative assessment and mapping of plant resources of easternghats. The medicinal plant species are recorded with help of tribal informants and local venders of who have practice and experience in the use of phytomedicines. The age of the informants ranged from 40-60 years. Interviews were conducted in a place where the informants were most comfortable. The information gathering localities are Mahaboobnagar (Achampet, Amrabad, Appapir, Farhabad, Jalipenta, Mallelatheertham, Vatuvarlapalli), Kurnool (Ahobilum, Chelama, Mahanandi, Motta, Velugodu), Prakasam (Chinnarutla, Erragondapalem, Ganjivaripalli, Garapenta, Nekkantipenta, Palutla, Peddacheruvu, Pulicheruvu, Pullalacheruvu). A quadrat of 10×10 m was laid to enumerate trees of above 10 cm girth at breast height (GBH), tree saplings, seedlings and shrubs were recorded by laying 5×5 m quadrates and herbs were recorded from 1×1 m quadrates. All the plants were identified up to species level by using available state, regional and local floras (Gamble and Fischer, 1915-1935, Ellis, 1987, Pullaiah, 1997 and Pullaiah and Alimoulali, 1997; Pullaiah and Chennaiah, 1997). The specimens were made into herbarium following standard methodology and finally conformed to the herbarium of Botanical Survey of India (BSI), Coimbatore.

RESULTS AND DISCUSSION

Only few dispensaries and primary health centers exist in tribal areas of Nallamalais. The doctor–to–people ratio is very less. The tribal people are completely dependent on herbal medicines for their health care. A total of 324 species belonging to 252 genera and 96 families, out of which 116 tree species of 40 families, 167 herbaceous species of 37 families and 41 shrub species of 19 families were recorded. A total of 52 diseases known to be cured / treated/ prevented with the usage of 261medicinal plant taxa were also recorded. Sixty six species are used for 5 major diseases such as Asthma, cardiac debility, diabetes, snake bite, scorpion sting (Table. 1). A maximum of 30 plant species are used for curing diabetes, followed by 29 species for asthma, 18 species snake bite, 13 species for scorpion sting and 12 species for cardiac debilities.

Knowledge about the curing system is transferred orally from generation to generation and place to place without any written documentation and many of the traditional methods have superstitious element. Moreover, lack of information about the traditional curing methods has resulted in confusion amongst users. Thus the present study has recommended the necessity of proper information of the real curing methods, along with the main characterstic features of the medicinal plants.

Table 1. Medicinal plants used by tribal communities curing for their diseases

Sl.No	Name of the plant	Family	Local name	Disease	Parts used
1	*Abelmoschus moschatus* Medik.	Malvaceae	Kasturi benda	Snake bite	Seeds
2	*Abrus precatorius* L.	Fabaceae	Gurivinda	Asthma	Seeds
3	*Acacia catechu* (L.f.). Willd	Mimosaceae	Nalla sandra	Asthma, diabetes	Bark
4	*Acacia nilotica* (L.) Willd. ex Delile	Mimosaceae	Nallathumma	Diabetes	Gum
5	*Acalypha indica* L.	Euphorbiaceae	Muripinda	Asthma, diabetes	Leaf juice
6	*Achyranthus aspera* L.	Amaranthaceae	Uttereni	Diabetes, asthma, snake bite, scorpion sting	Whole plant
7	*Adianthum incisum*	Adiant]aceae Forssk.	-	Skin diseases, diabetes, bone fracture	Leaves, Rhyzome
8	*Aegle marmelos* (L.) Correa.	Rutaceae	Maredu	Asthma, diabetes, cardiac debility	Leaves, fruits
9	*Aerva lanata* (L.) Juss.	Amaranthaceae	Pindikura	Diabetes	Roots
10	*Ailanthus excelsa* Roxb.	Simarubacaceae	Peddavepa	Asthma	Bark
11	*Albizia lebbeck* (L.) Benth.	Mimosaceae	Sirimanu	Asthma, snakebite	Bark,leaf, seeds

Sl.No	Name of the plant	Family	Local name	Disease	Parts used
12	*Albizia odoratisssima*	mimosaceae (L.f) Benth.	Konda chinduga	Diabetes, snake bite	Bark
13	*Alpinia malaccensis* (Burm.f.) Roscoe	Zingiberaceae	-	Diabetes	Rhyzome
14	*Andrographis nallamalayana* Gambel.	Acanthaceae	Nelavemu	Diabetes, snake bite, wounds	Leaves
15	*Andrographis paniculata* (Burm.f.) Wall.	Acanthaceae	Nelavemu	Diabetes, wounds snake bite	Whole plant
16	*Anisomeles indica* (L.) R.Br.	Lamiaceae	-	Scorpion sting, snake bite	Roots
17	*Anogeissus latifolia* (Roxb. Ex DC.)Wall.	Combretaceae	Chirumanu, Velama	Asthma, diabetes, scorpion sting,	Bark
18	*Argemone mexicana* L.	Pepaveraceae		snake bite Asthma, scorpion sting	Whole plant
19	*Argyrea nervosa* (Burm.f.) Boer	Convolvulaceae		Diabetes	Whole plant
20	*Aristolochia bracteolata* Lam.	Aristolochaceae	Gadida gadapa	Scorpion sting, snake bite	Whole plant
21	*Aristolochia tagala* Cham.	Aristolochaceae	Nalla Eswari	Scorpion sting, snake bite	Leaf, root
22	*Asparagus racemosus* Willd.	Liliaceae	Pilligaddalu	Diabetes	Roots
23	*Atalantia monophylla* (L.) Correa.	Rutaceae	Adavi nimma	Snake bite	Leaves, fruits
24	*Balanites roxburghii* Planch.	Balanitaceae	Garachettu	Snake bite	Leaves, fruits

Sl.No	Name of the plant	Family	Local name	Disease	Parts used
25	*Boswellia serreta* Roxb.	Bursaraceae	Anduga	Asthma	Leaves, Gum
26	*Buchanania lanzan* Spreng	Anacardiaceae	Sarapappu	Asthma	Fruits
27	*Cascabela thevetia* (L.) Lippold	Apocyanaceae	Pacha ganneru	Wounds	Roots
28	*Cassia fistula* L.	Caesalpi niaceae	Rela	Diabetes	Bark, fruits
29	*Centella asiatica* (L.) Urb.	Apiaceae	Saraswati aku	Asthma, memory	Leaves
30	*Cissus quadrangularis* L.	Vitaceae	Nalleru	Bone fracture	Stem paste
31	*Citrullus colocynthus* (L.) Schard.	Cucurbitaceae	Verripuccha	Snake bite	Fruits
32	*Clitoria ternatea* L.	Fabaceae	Sankhu puvvu	Asthma, snakebite	Leaf, flowers
33	*Darura metel* L.	Solanaceae	Nalla Ummetta	Asthma, scorpion sting	Leaf, seeds
34	*Datura stramonium* L.	Solanaceae	Tella ummetta	Asthma	Leaf powder
35	*Eclipta prostrata* (L.) L.	Asteraceae	Guntaga lagara	Asthma, cooling	Leaves
36	*Enteda pursitha* L.	Mimosaceae	Adavi chinta	Rheuma tism	Seed paste
37	*Euphorbia antiquorum* L.	Euphorbiaceae		Diabetes	Whole plant
38	*Euphorbia nivulia* Buch. - Ham.	Euphorbiaceae	Bonta jemudu	Diabetes	Stem paste
39	*Gloriosa superba* L.	Liliaceae	Adavi nabhi	Scorpion sting, snake bite	Rhyzome paste

Sl.No	Name of the plant	Family	Local name	Disease	Parts used
40	*Helicteres isora* L.	Sterculiaceae	-	Diabetes	Bark, root, fruit
41	*Jatropha glandulifera* Roxb.	Euphorbiaceae	Nepalam	Snake bite	Seeds
42	*Jatropha gossypifolia* L.	Euphorbiaceae	Seema nepalam	Snake bite	Seed oil
43	*Leucas aspera* (Willd.) Link	Lamiaceae	Thummi	Asthma, snake bite Scorpion sting	Whole plant
44	*Limonia acidissima* L.	Rutaceae	Velaga	Asthma, cardiac debility	Fruits
45	*Madhuca longifolia* (J.Kongi) J.F.	Sapotaceae	Ippa	Diabetes	Milky latex
46	*Mimosa pudica* L.	Mimosaceae	Attipatti	Diabetes, scorpion sting	Root paste
47	*Phyllanthus amarus* Schum. & Thonn.	Euphorbiaceae	Nela usiri	Diabetes, urinary disorders	Whole plant
48	*Phyllanthus emblica* L.	Euphorbiaceae	Usiri	Asthma, cardiac debility	Fruits
49	*Pterocarpus marsupium* Roxb.	Fabaceae	Yegisa	Diabetes, asthma	Heart wood
50	*Scilla hyacinthina* (Roth) J.F. Macbr.	Liliaceae	-	Cardiac debility	Bulb
51	*Solanum anguivi* Lam.	Solanaceae		Scorpion sting	Leaves
52	*Stachyterpheta jamaicensis* (L.) Vahl	Verbenaceae	-	Cardiac debility	Leaves
53	*Sterculia urens* Roxb.	Sterculiaceae	Tapasi	Diabetes	Gum

Sl.No	Name of the plant	Family	Local name	Disease	Parts used
54	*Strychnos nux-vomica* L.	Loganiaceae	Mushti	Asthma, diabetes' cardiac debility	Fruits, seeds
55	*Strychnos potatorum* L.f.	Loganiaceae	Chilla	Asthma, diabetes' cardiac debility	Fruits, seeds
56	*Syzygium alternifolium* (Wight) Walp.	Myrtaceae	-	Diabetes	Fruits, seeds
57	*Syzygium cumini* (L.) Skeel	Myrtaceae	Nerudu	Diabetes	Fruits, seeds
58	*Terminalia alata* Heyne ex Roth.	Combretaceae	-	Cardio tonic	Bark
59	*Terminalia arjuna* (Roxb. Ex DC.) Wight	Combretaceae	Tella maddi	Asthma, diabetes' cardiac debility	Bark, leaf, fruits
60	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Thandra	Asthma, diabetes' cardiac debility	Bark, leaf, fruits
61	*Terminalia chebula* Retz.	Combretaceae	Karakkaya	Asthma, diabetes' cardiac debility	Fruits
62	*Vanda tessellata* (Roxb.) Hook.	Orchidaceae	Bhajanika	Bone fracture	Leaves
63	*Vitex negundo* L.	Verbenaceae	Tella eswari	Asthma, wounds cardiac debility	Whole plant
64	*Ziziphus mauritiana* Lam.	Rhamnaceae	Regu	Asthma	Fruits
65	*Ziziphus rugosa* Lam.	Rhamnaceae	Konda Regu	Asthma	Root-bark, fruit
66	*Ziziphus zylopyrus* (Retz.) Willd.	Rhamnaceae	Gotika	Asthma	Root-bark, fruit

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EVALUATION OF CHILLI (*Capsicum annum* L.) VARIETIES IN HIGH ALTITUDE AND TRIBAL ZONE OF SRIKAKULAM DISTRICT OF ANDHRA PRADESH.

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ABSTRACT

The yield performance and association between yield and its components were studied in 5 varieties of chilli during rabi 2004 and 2005 at Agricultural Research Station, Seethampeta. The variety LCA 424 was short in height but produced long pods with maximum 100 pod weight than the other improved varieties CA960, LCA 353 and LCA 334 as well as the local check. It produced significantly more pod yield of 13.1 t ha^{-1} during 2004 and 8.3 t ha^{-1} during 2005 than all others. The mean pod yield was 10.7 t ha^{-1}. The local variety produced low yield of 2.0 and 3.6 t ha^{-1} during 2004 and 2005 respectively with a mean of only 2.8 t ha^{-1}. The genotypic correlation recorded highly significant association between 100 pod weight and yield.

Chilli is one of the widely cultivated vegetable cum spice crops of India. It is grown in an area of 8.06 lakh ha with a production of 12.98 lakh tones. Andhra Pradesh is the largest chilli producing state contributing about 59% of total production. It is cultivated on 2.23 lakh ha with production of 7.72 lakh tonnes (CMIE, 2008). It is grown on commercial scale for both green and dry chilli purpose. Among the various spices produced in India, per capita consumption is highest for chillies. It is widely cultivated in almost all the climatic conditions i.e., in warm temperature, tropical and subtropical countries. Many varieties of chilli are available in India which are region specific varying in plant habit, yield and quality parameters (Singh *et al.* 2005).

The performance of chilli grown in tribal zone of Andhra Pradesh has shown an immense potential for its commercial cultivation in large area. However, the information on varieties suitable to this region is scanty and no systematic efforts have been made to evaluate the improved chilli cultivars and study their suitability to this region during rabi season. Hence, the present investigation was under taken to identify a suitable variety for High Altitude and Tribal Zone of Andhra Pradesh during rabi season.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, Seethampeta, Srikakulam district of Andhra Pradesh during rabi 2004 and 2005. The available phosphorus and potassium content were 24 and 245 kg ha^{-1} respectively. The soil type was clay loam

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and pH was 6.82. The experiment was laid out in randomized block design with five varieties viz LCA424, CA 960, LCA353, LCA334 and local as a check and tested in 4 replications. The four improved varieties were released from Regional Agricultural Research Station, Lam, Guntur. The nurseries were raised during last week of September and the seedlings were transplanted at a spacing of 50 x 15 cm in 6.0 x 4.5 m plots during first fortnight of November. Fertilizers were applied at the rate of 60-30-50 kg NPK per hectare. The recommended cultural practices were followed. Observations on plant height, plant spread, number of pods per plant, 100 pod weight, pod length and green pod yield were recorded. Data on mature green fruits harvested six times at different intervals was pooled and total yield was estimated. The data was statistically analysed year wise as described by Panse and Sukhatmea (1978) and the correlations between the yield and yield attributing characters were calculated according to the formulae given by Allard (1960).

RESULTS AND DISCUSSION

The data on growth, yield attributes and yield of green chillies presented in table 1 showed substantial differences among the varieties. The local variety was tall with maximum spread. The improved variety LCA334 also attained equally tall height both in 2004 and 2005 but produced the largest number of 102.9 pods per plant in the first year and 81.0 pods in the second year. The local variety produced significantly less number of only 44.5 and 40.0 pods per plant in the corresponding years. The performance of LCA353 was also significantly superior to the local variety. It produced 66.0 pods in 2004 and 75.5 pods per plant in 2005. The hundred pod weight of these two varieties was on par with the local in both the years. The 100 pod weight of CA960 was significantly more than these two improved and the local variety. But, LCA424 produced heavy pods with maximum weight of 361.6 and 485.1g. This was significantly more. The length of these pods was also significantly more than all other varieties.

Owing to the large size and heavy weight of 100 pods, the green pod yield of chilli variety LCA 424 was as high as 13.1 t ha^{-1} in 2004 and 8.3 t ha^{-1} in 2005. This was significantly more than rest of the varieties in the first year while it was on par with CA960 in the second year. The pooled analysis showed that the mean green chilli yield of 10.7 t ha^{-1} was also significantly more than others. The higher yield potential of the LCA424 may be attributed to its genetic make-up. The varieties CA960 and LCA334 were also high yielders compared to control. They produced significantly more yield both in 2004 and 2005 as well as on the basis of pooled analysis. Kameswari *et al* (2006) and Kawarkhe *et al* (1989) also reported the superiority of the variety CA960 under rainfed conditions of Pandirimamidi and irrigated conditions of Vidarbha region because of its higher yield with desirable fruit characters.

Though the local variety recorded maximum plant height and spread, it produced less number of pods per plant and hence the green pod yield was only 2.0 t ha^{-1} in the first year and 3.6 t ha^{-1} in the second year. The lower yield in other varieties may be due to poor adaptability to the tract and this is supported by Elangovan *et al* (1982) and Munshi *et al* (2000).

The data on relationship among different characters and pod yield of green chillies did not show significant phenotypic correlations (Table-2). The genotypic correlations were significant and negative between plant height and 100 pod weight and between plant spread and number of pods per plant but, the genotypic association was positive and highly significant between 100 pod weight and yield. Pawadae *et al* (1995) also observed positive and significant contribution of 100 pod weight of green chillies on yield.

The study showed that the green chilli variety LCA424 produce high pod yield during the rabi season in the tribal zone of Srikakulam district. If the seed of this variety is not available, CA960 is the next best choice.

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Table 1. Performance of chilli varieties during rabi season in tribal zone of Srikakulam district.

Variety	Plant height (cm)		Plant spread (cm)		Number of pods per plant		100 pod weight (g)		Pod length (cm)		Green pod yield (t ha^{-1})		Mean yield (t ha^{-1})
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	
CA960	105.3	63.2	50.0	32.1	89.2	41.7	258.8	382.0	5.0	6.7	8.8	7.1	7.0
LCA 424	86.2	54.1	56.5	37.0	87.3	42.7	361.6	485.1	9.9	9.5	13.1	8.3	10.7
LCA 353	96.8	63.9	46.4	31.4	66.0	75.5	158.2	264.6	7.4	7.8	3.6	5.7	6.4
LCA334	106.0	78.8	49.9	33.7	102.8	81.0	140.8	228.9	6.2	7.2	5.9	5.9	5.9
Local	106.7	72.7	59.4	35.3	44.4	40.0	114.0	201.3	6.9	7.8	2.0	3.6	2.8
SE ±	3.1	4.7	2.9	1.5	3.9	9.7	29.9	35.1	0.4	0.4	0.9	1.3	1.2
CD at 5%	7.6	10.2	6.5	3.4	8.5	21.3	65.2	76.5	1.0	1.1	2.1	2.8	2.6

Table2. Phenotypic (P) and genotypic (G) correlations for six characters in five chilli varieties.

		Plant spread	Number of Pods /plant	100 pod weight	Pod length	Pod yield
Plant height	P	-0.0600	0.3307	-0.7534	-0.7113	-0.5730
	G	-0.2282	0.1064	-0.8881 *	-0.8130	-0.7208
Plant spread	P		-0.3501	0.1702	0.4057	0.1068
	G		-1.4508 **	0.2274	0.5598	0.0359
Number of Pods/Plant	P			-0.1242	-0.0821	-0.0492
	G			-0.5410	-0.3000	-0.1532
100 Pod weight	P				0.5413	0.8646
	G				0.5222	0.9765 **
Pod length	P					0.3441
	G					0.3514

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LENGTH OF CROP GROWING SEASON AND BUDGETING OF SOIL MOISTURE FOR INTERCROPPING STRATEGIES IN CASTOR (*Ricinus communis* L.)

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ABSTRACT

Rainfall analysis represented by precipitation curve through plots of P/PET revealed that the crop growing season ranged from 24 to 48 meteorological standard weeks at Ranga Reddy, (Andhra Pradesh, India). Hence crops of 170 days duration can be grown. The wide row spaced crops can be intercropped with short and medium duration crops that mature in the moist period in about 100 days. The budgeting of moisture in the soil showed that the water requirement satisfaction index (WRSI) was 100% from 28 to 41 standard weeks in the first year and from 29 to 41 standard weeks in the second year. The soil held a surplus of 668 mm moisture due to heavy rains from 30 to 37 standard weeks in the second year. This impeded the drainage and adversely affected the growth in the second year resulting in lower yields of all the crops than in the previous year. The rainfall in the later period was less than potential evapotranspiration. Therefore intercrops *viz.* pearlmillet maturing in 75 days, sunflower in 80 days, soybean in 90 days and sorghum in 105 days were highly competitive and did not increase the castor equivalent yield over the sole crop. The intercropping of short duration pulses like greengram and blackgram in castor resulted in significantly higher castor equivalent yield during both the years.

Castor is mostly cultivated under rainfed conditions in marginal and sub-marginal shallow soils with low input by the resource poor farmers in Andhra Pradesh, Tamil Nadu, Karnataka and Orissa. Andhra Pradesh ranks second in area and production next to Gujarat. In Andhra Pradesh, it is mainly cultivated in the districts of Nalgonda, Mahbubnagar and Ranga Reddy. The crop is generally grown under neglected conditions in wide rows and in soils of coarse texture and poor fertility status under undependable quantity of rain with erratic distribution. Wider fluctuations in rainfall and its distribution received through south-west monsoon during the crop growth period leads to wide variation in productivity. Castor is grown both as a sole crop and often as a mixed or inter crop. The row spaces offer a congenial micro environment for the weeds to develop and compete with the crop thereby severely reducing the yield of castor. These inter-row spaces can be best exploited for growing compatible intercrops and to obtain more production per unit area while minimizing the risk of complete crop failure in situations of insufficient rainfall as castor being a long duration crop with drought tolerance. The slow growth habit of castor in the initial stages favors intercropping of short duration and quick growing crops to exploit the land resources more efficiently.

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A scientific approach is required to workout the budget of soil moisture and estimate the length of crop growing season to understand the options available for crops and cropping systems for successful adaptation in an agroecological region. This prompted the present investigation to search for the best combinations for intercropping in castor in the agro climatic region of Southern Telengana Zone in Andhra Pradesh.

MATERIALS AND METHODS

The field experiments were conducted at the National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad in the *kharif* season on Alfisols under rainfed conditions during two consecutive seasons of 2007 and 2008. Length of crop growing season was worked out as per the procedure outlined by Cocheme and Franquin (1967). The weekly rainfall data of thirty four years (1975 to 2008) at Agricultural Research Institute, Rajendranagar was used. The potential evapotranspiration (PET) was estimated following method suggested by Blaney and Criddle (1950) . The ratio of precipitation to potential evapotranspiration (P/PET) in each week was plotted on a graph and a smooth curve was drawn passing through these points. The precipitation curve was sketched out for intersections of weekly P/PET on Y axis and standard week on X axis. The FAO water balance model (Frere and Popov, 1979 and FAO, 1986) as given by Reddy (1991) was used in the present investigation. The crop coefficients were extracted from FAO, Irrigation and Drainage, paper No. 33 (Doorenbos and Kassam, 1979). The soil was sandy clay loam in texture with available water holding capacity of 92 mm per metre depth. There was a rainfall of 361.2 mm distributed in 13 weeks during the crop growing period in 2007. A higher amount of 843.9 mm rainfall was distributed over a period of 11 weeks during the second year. The number of rainy days was 32 each in both the years.

For estimation of length of growing season, castor variety, "*Kranti*" of 170 days duration was grown. The variety '*Kranti*' was chosen as it is high yielding with higher oil content of 48-50%. It was grown at a uniform row spacing of 90 cm or paired rows of 120/60 cm with an intra row spacing of 20 cm. The crop was grown sole in these two planting patterns and intercropped with one and two rows each of sorghum and sunflower and two and three rows each of pearlmillet, greengram, blackgram and soybean between the uniform and paired rows of castor respectively. These 14 treatments were laid out in a randomized block design. Castor was fertilized with 80:60:40 kg N, P_2O_5 and K_2O ha^{-1}in sole and intercropped systems. The intercrops were also fertilized in proportion to their population. All the recommended agronomical practices were followed and the crops were raised completely as rainfed. The castor equivalent yield was calculated by using the following formula.

$$\text{Castor equivalent yield (kg ha}^{-1}\text{)} = \frac{Y_i \times P_i}{P_c} + \text{Yield of castor (kg ha}^{-1}\text{)}$$

Where Y_i = Yield of intercrop (kg ha^{-1})

P_i = Price of intercrop (Rs kg^{-1})

P_c = Price of castor (Rs kg^{-1})

RESULTS AND DISCUSSION

Length of crop growing period

The bioclimate model to estimate the length of crop growing period in the Ranga Reddy district of Andhra Pradesh during which moisture is available for the crops is sketched in figure 1.

The analysis of past thirty four years weekly mean data of P/PET indicated that the crop growing season for Ranga Reddy district spans over 25 weeks commencing from 24th to 48th standard week. The ratio of 0.1 P/PET commences in the 18th MSW. The P/PET reaches 0.5 by 24th standard week. During this period of summer showers, the soils can be prepared for sowing. The P/PET ranged from 0.5 to 1.0 during 24 to 28 standard week. This corresponds to 2nd week of June to 2nd week of July. This is the moist period. The crops are sown during this one month period. The humid period runs from 28 to 38 week when P/PET is ^{3} 1.0. This is the time when the soils are moist and congenial for the reproductive growth phase from flowering to the development of economic products. This corresponds to the time from 3rd week of July to 3rd week of September. The P/PET then recedes from 1.0 to 0.5 until 42 standard week coinciding with the 3rd week of October. The water requirement of the crops is low in this moist period and hence the receding moisture is sufficient for ripening. This is followed by further recession of moisture until P/PET reach 0.1 by 48 meteorological standard week at the end of November. During this period, the crops mature and are ready for harvest. The bioclimate model thus indicated that the cropping season for Ranga Reddy district span over 24 weeks from 24 to 48 standard week. Since, the estimated moist regime of the soils is for 14 weeks from 24th to 38th standard week short to medium duration crops can also be intercropped successfully. This bioclimate model will be very much helpful in crop planning. The results from this study confirm that long duration crops of about 170 days can be successfully grown in this region to suit the rainfall pattern and soil moisture regime. The wide row spaced crops can be intercropped with short and medium duration crops that mature in the moist period in about 100 days.

Budgeting of soil moisture

The data on budgeting of soil moisture as a balance between its loss through PET and the precipitation after meeting the crop water requirement is furnished in tables 1 and 2. The PET ranged from 21 to 38 mm per week during the crop growth period in 2007 and from 25 to 37 mm per week in 2008. The total PET losses were 725 mm during the crop growth period while rainfall of only 361.2 mm was received in 32 rainy days from 29th to 44th MSW

during 2007. In the second year, 793 mm moisture was lost as PET. This was compensated by the high rainfall of 843.9 mm received in 32 rainy days but its occurence was restricted within a short period of 30th to 40th MSW. The computed water requirement as a function of potential evapotanspiration and crop coefficient of castor varied for different weeks during both the years. The total water requirement was 486.2 mm during 2007 and 529.9 mm during 2008. Thus the precipitation was deficit by 125 mm less than the water requirement of castor in the first year. A surplus of 314 mm rainfall was recorded in the second year.

The crops were sown on 16th July in the 29 standard week during 2007. By this time, the soil was charged with 227.1 mm rainfall since the 3rd week of April. The WRSI was 100% at the time of sowing during 2007. The soil retained 61.4 mm moisture. The subsequent week was dry without rain. The soil moisture retention reduced to 53.9 mm. This was followed by precipitation continuously every week until 7th October coinciding with the 40 standard week and the WRSI was 100% in all these weeks. Subsequently, the precipitation was less than the water requirement of castor in every week until harvest. Hence, the soil moisture retention reduced to 77.9, 50.9, and 13.5 mm during 39, 40 and 41 standard week respectively. Still the water requirement satisfaction index was 100%. Hence, castor and all the intercrops did not face severe water scarcity during the 50% flowering stage. The soil was deficit of 14.7 mm moisture in the 42 standard week. The deficit increased consistently until the final harvest of castor. The WRSI reduced consistently from 96.98% in 42nd week to 22.07 in 47th standard week. This index turned negative from 48th week and increased in the successive weeks until the final harvest of castor.

The first picking of castor occurred in the 42nd standard week when the soil had 96.98% WRSI. The second picking was in the 47 standard week. At this time, the soil had a deficit of 110.75 mm and yet the WRSI was positive with the value of 22.07. The third picking was taken up in the 50th standard week. The soil was severely starved of moisture with a deficit of 147.25 mm and WRSI was -61.28. The fourth and final picking during the first standard week was most severely affected. The soil was deficit of 180.45 mm moisture and WRSI was-165.96.

The precipitation exceeded the water requirement of castor since its sowing in 30 standard week until 37 standard week during 2008. The soil remained saturated with surplus water for eight weeks. This hampered the aeration in the rhizosphere and stunted the crop growth. The soil was slushy with 90 mm surplus water over the water holding capacity of 92 mm. Hence, the crop yields were low. The 38 and 39 standard weeks were dry. The soil moisture retention reduced to 62.8 and 29.8 mm. The WRSI was 100%. A rainfall of 49.4 mm in the 40 standard week exceeded the water requirement and there was soil moisture retention of 40.7 mm. The saturated soil was also harmful to these crops. They yielded low than in the first year. Rainfall virtually ceased from 41 standard week until harvest of castor except in the 48 standard week. The soil was deficit of moisture from the 42 standard week and the

magnitude of dryness increased consistently. The WRSI reduced sharp from 94.15 in the 42 standard week to 14.42 in the 46 standard week. The first picking of castor was during the 43 week. But the second picking of castor in the 48 week, third picking in the 51 week and final picking in the 52 standard week occurred under highly stressed conditions of soil moisture indicated by the WRSI of -50.72, -167.90, and -308.31. This reduced the seed yield seriously than in the previous year. On the other hand, the yield of intercrops was low than in the previous year due to surplus moisture. Hence, in spite of 482.7 mm more rainfall in the second year over 361.20 mm in the first year, the yields of castor and intercrops were severely reduced mainly due to the unfavourable moisture distribution pattern. The budgeting of weekly water balance indicated that the water requirement satisfaction index was 100 % till 41 standard week. Hence castor and intercrops did not face severe water scarcity during their 50% flowering stage. The surplus water of 668 mm resulted in saturated condition of the soil for eight weeks, which hampered the aeration in the rhizosphere and resulted in stunted growth and poor yields of crops during the second year. The WRSI reduced to minus values from 48 standard week and castor crop experienced soil moisture stress till harvest.

The budgeting of moisture in the soil showed that the WRSI was 100% from 28 to 41 standard week in the first year and from 29 to 41 standard week in the second year. The soil held a surplus of 668 mm moisture due to heavy rains from 30 to 37 standard week in the second year. This impeded the drainage and in turn affected the growth resulting in less yields of all the crops than in the first year.

Castor seed and equivalent yield

The castor seed yield was differentially influenced by different intercrops (Table 3). During the investigation years, castor intercropped with blackgram yielded on par with the sole crop. The observations are in line with the earlier investigations of Padmavathi and Raghavaiah (2004) and Porwal *et al*. (2006). Additionally there was a bonus production of 313 and 255 kg seed ha^{-1} from blackgram. Pearlmillet and sorghum were highly competitive and reduced the castor yields drastically. Greengram, sunflower and soybean grew vigorously and competed with castor for higher resource utilization thereby reducing the yield of castor. Similar reduction in castor yield with greengram was earlier reported by Patel *et al*. (2002). The total productivity in terms of castor equivalent yield enhanced significantly by intercropping blackgram and greengram during the two years. Intercropping of castor with sorghum significantly reduced the castor equivalent yield during both the years. Castor equivalent yields due to intercropping of pearlmillet, soybean or sunflower were at par with sole crop.

The results of present investigation indicated that initial two months of the growing season of castor can be best exploited by intercropping blackgram or greengram. This could provide higher advantage of increasing the total productivity in terms of castor equivalent yield concurrently providing proteinaceous food for man and fodder for animal from the same piece of land.

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Table 1. Weekly water balance pertaining to castor crop during *Kharif*, 2007

AWHC = 92 mm

SW (mm)	PET (mm)	CC	WR (mm)	PP (mm)	PP-WR (mm)	SMR (mm)	SURPLUS (mm)	DEFICIT (mm)	WRSI%
28	38.00	...	...	...	...	92.00	...	...	100.00
29	37.00	...	37.00	6.40	-30.60	61.40	...	...	100.00
30	30.00	0.25	7.50	0.00	-7.50	53.90	...	...	100.00
31	26.00	0.25	6.50	54.00	47.50	92.00	9.40	...	100.00
32	31.00	0.30	9.30	20.70	11.40	92.00	11.40	...	100.00
33	38.00	0.30	11.40	5.00	-6.40	85.60	...	...	100.00
34	31.00	0.50	15.50	48.00	32.50	92.00	26.10	...	100.00
35	28.00	0.50	14.00	56.00	42.00	92.00	42.00	...	100.00
36	28.00	0.50	14.00	24.40	10.40	92.00	10.40	...	100.00
37	25.00	1.00	25.00	39.20	14.20	92.00	14.20	...	100.00
38	21.00	1.00	21.00	53.60	32.60	92.00	32.60	...	100.00
39	34.00	1.10	37.40	23.30	-14.10	77.90	...	...	100.00
40	30.00	1.10	33.00	6.00	-27.00	50.90	...	...	100.00
41	34.00	1.10	37.40	0.00	-37.40	13.50	...	...	100.00
42	31.00	1.00	31.00	2.80	-28.20	...	...	14.70	96.98
43	31.00	1.00	31.00	0.00	-31.00	...	...	45.70	87.58
44	27.00	0.75	20.25	21.80	1.55	0.2	...	45.50	78.22
45	33.00	0.75	24.75	0.00	-24.75	...	...	70.25	63.77
46	29.00	0.75	21.75	0.00	-21.75	...	...	92.00	44.85
47	25.00	0.75	18.75	0.00	-18.75	...	...	110.75	22.07
48	25.00	0.50	12.50	0.00	-12.50	...	...	123.25	-3.28
49	23.00	0.50	11.50	0.00	-11.50	...	...	134.75	-31.00
50	25.00	0.50	12.50	0.00	-12.50	...	...	147.25	-61.28
51	28.00	0.40	11.20	0.00	-11.20	...	...	158.45	-93.87
52	29.00	0.40	11.60	0.00	-11.60	...	...	170.05	-128.85
1	26.00	0.40	10.40	0.00	-10.40	...	...	180.45	-165.96
Total	**725.00**	**...**	**486.20**	**361.20**	**-125.00**	**...**	**146.10**	**180.45**	**...**

SW: Meteorological standard week; PET: Potential evapotranspiration; CC: Crop coefficient; WR: Water requirement; PP: Precipitation; SMR: Soil moisture retention; S:Surplus; D: Deficit; WRSI: Water requirement satisfaction index; AWHC: Available water holding capacity

Table 2. Weekly water balance pertaining to castor crop during *Kharif*, 2008

AWHC=92 mm

SW (mm)	PET (mm)	CC	WR (mm)	PP (mm)	PP-WR (mm)	SMR (mm)	SURPLUS (mm)	DEFICIT (mm)	WRSI%
29	...	...	...	...	...	92.00	...	...	100.00
30	26.00	...	26.00	65.20	39.20	92.00	39.20	...	100.00
31	29.00	0.25	7.25	120.20	112.95	92.00	112.95	...	100.00
32	28.00	0.25	7.00	188.80	181.80	92.00	181.80	...	100.00
33	34.00	0.30	10.20	23.20	13.00	92.00	13.00	...	100.00
34	33.00	0.30	9.90	157.30	147.40	92.00	145.75	...	100.00
35	35.00	0.50	17.50	18.40	0.90	92.00	4.40	...	100.00
36	34.00	0.50	17.00	98.20	81.20	92.00	81.20	...	100.00
37	29.00	0.50	14.50	104.60	90.10	92.00	90.10	...	100.00
38	31.00	1.00	31.00	1.80	-29.20	62.80	...	...	100.00
39	33.00	1.00	33.00	0.00	-33.00	29.80	...	...	100.00
40	35.00	1.10	38.50	49.40	10.90	40.70	...	...	100.00
41	32.00	1.10	35.20	3.00	-32.20	8.50	...	...	100.00
42	37.00	1.10	40.70	1.20	-39.50	...	...	31.00	94.15
43	28.00	1.00	28.00	0.00	-28.00	...	...	59.00	83.02
44	36.00	1.00	36.00	0.00	-36.00	...	...	95.00	65.09
45	37.00	0.75	27.75	0.00	-27.75	...	...	122.75	41.92
46	32.00	0.75	24.00	1.00	-23.00	...	...	145.75	14.42
47	31.00	0.75	23.25	0.00	-23.25	...	...	169.00	-17.47
48	25.00	0.75	18.75	11.60	-7.15	...	...	176.15	-50.72
49	32.00	0.50	16.00	0.00	-16.00	...	...	192.15	-86.98
50	29.00	0.50	14.50	0.00	-14.50	...	...	206.65	-125.98
51	31.00	0.50	15.50	0.00	-15.50	...	...	222.15	-167.90
52	33.00	0.40	13.20	0.00	-13.20	...	...	235.35	-212.31
1	32.00	0.40	12.80	0.00	-12.80	...	...	248.15	-259.14
2	31.00	0.40	12.40	0.00	-12.40	...	...	260.55	-308.31
Total	**793.00**	**...**	**529.90**	**843.90**	**314.00**	...	**668.40**	**260.55**	**....**

SW: Meteorological standard week; PET: Potential evapotranspiration; CC: Crop coefficient; WR: Water requirement; PP: Precipitation; SMR: Soil moisture retention; S:Surplus; D: Deficit; WRSI: Water requirement satisfaction index; AWHC: Available water holding capacity

Table 3. Seed yields of castor, intercrops and castor equivalent yield (kg ha^{-1}) as influenced by intercropping

Treatment	*Kharif* -2007			*Kharif* -2008		
	Castor	Intercrop	Castor equivalent yield	Castor	Intercrop equivalent yield	Castor
Sole castor	897	-	897	600		600
Castor +Sorghum	477	232	579	310	181	393
Castor +Pearlmillet	338	1114	828	221	1026	698
Castor +Greengram	484	719	1116	435	449	917
Castor +Blackgram	878	313	1153	571	255	845
Castor +Soybean	702	350	912	432	225	577
Castor +Sunflower	620	296	857	305	276	581
SEm±	30		48	30		60
CD at 5%	89		141	89		175

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ADSORPTION OF OXADIARGYL IN VERTISOLS AND ALFISOLS OF ANDHRA PRADESH

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ABSTRACT

Adsorption of oxadiargyl was carried out on soils collected from different agroclimatic zones of Andhra Pradesh using batch equilibration technique. The extent of adsorption varied from 29.4 to 81.20 mg 5 g^{-1} at higher concentration i.e 35 mg kg^{-1}. It varied from 4.39 to 12.00 ug 5 g^{-1} at lower concentration 5 mg kg^{-1}. The per cent adsorption was more in vertisols than alfisols. Adsorption isotherms were predominantly parabolic in nature with a subdued S-character confined mostly to initial stages of adsorption. Freundlich constants K_f, n and K_{foc} varied from 0.01 to 2.63, 0.70 to 1.10 and 3.24 to 333.33, respectively in the alfisols. In the vertisols constants K_f, n and K_{foc} varied from 0.012 to 4.266, 0.2 to 1.11 and 14.81 to 289.13. The langmnir constant (K_L) ranged from 0.901 to 3.85 in vertisols. The adsorption maxima was positive and significantly correlated with organic carbon content. Freundlich 'K_s' values which indicate the extent of binding of herbicide to the soil constituents were positivily and significantly correlated with organic carbon, clay content and clay + organic carbon. The positive and significant correlation between adsorption of oxadiargyl and also highly significant and positive correlation between adsorption parameters and clay + OC (0.05056 **, 0.4254* & 0.4070*).

Adsorption is an important process for determining the ultimate fate of organic chemicals in soils because detoxification, metabolism, microbial uptake and mobilization are operative only on the non sorbed fraction of the molecules. The fate of herbicides in soil is mainly governed by transport, retention and transformation processes. Although retention includes all processes that prevent / reduce the movement of herbicides in soils, the primary means of retention is sorption of herbicides on soil constituents (Koskinen and Harper, 1990).

Thus, sorption of herbicides by soil particles directly or indirectly controls the fate of herbicides, which depends mainly on the nature of the herbicide, soil organic matter, soil reaction, type and amount of clay (Shanthi *et al*., 1997 and Mitra *et al*., 2001). Oxadiargyl (5-tert butyl-3-(2,4 dichloro-5-(prop-2ynyloxy) phenyl) – 1, 3, 4 – oxadiazol-2 (3H)-one) is fairly persistent chemical, exhibits residual toxicity to the succeeding crops (Pesticide Manual 1999). Oxadiargyl is a pre-emergence herbicide mostly used in paddy and vegetables but information on its adsorption is meager. Hence, a laboratory study was conducted to study the adsorption of oxadiargyl in different types of soils of Andhra Pradesh and the data was

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subjected to mathematical analysis by using Freundlich, Langmuir, Raman and Rao (1984) equations and to evaluate the influence of soil physico-chemical properties with adsorption parameters by correlation coefficients.

MATERIALS AND METHODS

Experiments were conducted at All India Coordinated Research Programme on Weed Control, Acharya N.G. Ranga Agricultural University, Hyderabad, with 25 soils (alfisols and vertisols) collected from seven agroclimatic zones of Andhra Pradesh. Representative soil samples were collected from the surface horizon with no background of oxadiargyl application. The soils were air dried and passed through a 2 mm sieve. The physico-chemical properties of these soils were analyzed by using standard proceducres (Jackson, 1979). Technical grade oxadiargyl (98% purity) was used in the present study. Adsorption studies were conducted in 25 different soils using the batch equilibration technique. Five grams of 2 mm sieved soils were equilibrated with 20 mL of oxadiargyl solutions of various concentrations ranging from 0 to 35 ug / mL at 27+2^{0}C in 20 mL capacity bottles for 24 h with intermittent shaking. Ionic strength was maintained at 0.01 M $CaCl_2$. After 24 h, the slurry was centrifuged at 5000 rpm for 15 minutes. In all the adsorption experiments, 0.01 M $CaCl_2$ was used as background electrolyte to suppress non-specific adsorption and to simulate natural conditions found in many soils. It facilitates the separation of solid material from aqueous solution after equilibration. Identical soil blanks minus the herbicides were maintained. The absorbance for each treatment and the corresponding blank were measured at 226 mm for oxadiargyl. The difference was taken as the actual equilibrium absorbance for which the concentration was calculated with references to the calibration curve. The amount of herbicide adsorbed per gram of soil was calculated from the difference in the initial and equilibrium concentrations. The supernatant was drawn and the oxadiargyl concentration was determined using UV spectrophotometer (GS570ISS) at 226 nm and the quantity adsorbed was calculated.

Quantitative treatment of adsorption isotherms:

The data was fitted to Freundlich and Langmuir adsorption equations. Recognizing the importance of organic carbon and to describe the adsorption in diverse soils by single parameter Shanthi *et al.(1997)* expressed the adsorption as an organic carbon adsorption coefficient (K_{foc}).

$$K_{foc} = \frac{K_f}{\text{\% organic carbon}} \times 100$$

Where K_{foc} is the adsorption coefficient per unit weight of organic carbon.

There is no report on the mathematical characterization of S-shaped isotherms. They are a combination of Freundlich type x/m = KC 1/n where I/n is >1 in initial stage and <1 in later parts.

An attempt was made by Raman and Ranga Rao (1984) and Raman and Rao (1984) to mathematically characterize a complete S-shaped isotherm from an analogy of growth curves of crystal growth or heterogenous precifitation of sparingly soluble substance from a saturated solution. The similarily lies purely in the shapes of growth curves in all these cases, so that similarity mathematical equation can be applied. Thus the equation-I was used to describe S-shaped isotherms.

$$\frac{df}{dc} = Kf^{2/3}(1-f) - I$$

where $\frac{df}{dc}$ = rate of increase of adsorption sites with concentration

f = fraction of herbicide adsorbed at equilibrium concentration c

To obtain the value of k, the integrated form of equation-I was used

$$X = \frac{(f^{2/3} + f^{1/3} + 1)}{(1-f)} + \sqrt{3}\ \tan^{-1}\ \frac{2f^{1/3}+1}{+\sqrt{3}}$$

$$K\,c + \sqrt{3}\ \tan^{-1}\ \frac{1}{\sqrt{3}}$$

Raman and Ranga Rao (1984) applied this equation to the adsorption of methabenzthiazuron on six soils of Hyderabad. For applying this equation, the value of X was calculated for f values ranging from 0.1 to 0.8. For each value, the corresponding value of equilibrium concentration was from the adsorption isotherms. Simple correlations were worked out between the adsorption parameters and soil properties.

RESULTS AND DISCUSSION

Physicochemical Properties of Soils

The pH of the soil samples varied from 5.49 to 8.65 and total soluble salt content from 0.10 to 0.46 dS m^{-1}. Nine soil samples were low in organic carbon content (0.23 to 0.45%), whereas the medium organic carbon content (0.52 to 0.73%) was observed in 11 soil samples and the highest content of organic carbon (0.75 to 1.06%) was observed in 5 soil samples. The sand, silt and clay content ranged from 41.4 to 86.4, 0.4 to 34 and 11.6 to 41.6%, respectively. The soils were sandy loam to clay in texture (Table 1).

Adsorption isotherms

The adsorption isotherms of oxadiargyl were S-shaped in nature, a common feature of the adsorption of most neutral organic chemicals on soil. However, L-shaped isotherms were obtained in alfisols.

The adsorption of oxadiargyl, in all the soils increased with increase in concentrations of oxadiargyl added. This phenomenon is quite common in the adsorption studies, suggesting that the adsorption sites were not saturated at concentrations used (Laird *et al*. 1992). The extent of adsorption varied from 29.4 to 81.20 mg 5 kg^{-1} at higher concentration i.e. 35 mg kg^{-1}. It varied from 4.39 to 12.00 mg 5 kg^{-1} at lower concentration of 5 mg kg^{-1}. The adsorption of the herbicides was greater in vertisols than alfisols.

Adsorption parameters

From the data on the quantities of oxadiargyl added, quantities adsorbed and the corresponding equilibrium solution concentration, the adsorption isotherms for all the soils were constructed as per the Freundlich and Langmuir equations, since this could be applied to such heterogeneous systems like soil- pesticide water suspension (Priya *et al*. 2006).

Adsorption isotherms were predominantly parabolic in nature with a subdued S-character confined mostly to initial stages of adsorption. The tendency for S-shaped character indicates a stronger initial competition for water molecules to the surface as compared to herbicides. The S-shape thus reflects the initial resistance to the adsorption of herbicides to overcome later by the cooperative effect of adsorbed molecules. Soils low to medium in organic carbon have a tendency to give S-shaped isotherms on account of their hydrophilic nature as compared to soils high in organic carbon, which lend to be hydrophobic.

Freundlich, Langmuir and Raman and Rao constants

The values of Freundlich constants 'K_f' 'n' and K_{foc} for adsorption of oxadiagyl on vertisols and alfisols are presented in table 3.

Freundlich constant K_f or adsorption maxima is related to the strength of binding and depends on temperature and 'n' is related to the intensity of binding.

Freundlich constants K_f, n and K_{foc} varied from 0.01 to 2.63 to 1.10 and 3.24 to 333.33 respectively in the alfisols. In all the vertisols, the constants K_f, n and K_{foc} varied from 0.012 to 4.266, 0.2 to 1.11 and 14.81 to 289.13 Langmuir constant (K_L) ranged from 0.901 to 3.85 is vertisol.

A new mathematical equation developed by Raman (1981) was also tried to quantify the adsorption data. The 'k' value, coefficient of increase in adsorption was obtained from slope of ë vs.c varied which from 0.08 to 0.22 vertisols and 0.07 to Alfisols 0.20 for Alfisols.

Correlation coefficients

The adsorption maxima was positively and significantly correlated with organic carbon content. Freundlich 'K_f' values, which indicate the extent of binding of herbicide to the soil constituents, were positively and significantly correlated with organic carbon, clay and clay + organic carbon. The positive and significant correlation between adsorption parameters and clay content indicate the importance of clay content in the adsorption of oxadiargyl. Another important finding was a highly significant and positive correlation between adsorption parameter and clay + OC (0.5056**, 0.4254* and 0.4070*), indicating that the clay upon intimate association with organic mater may cause some modifications of their adsorption capacity and they may complement one another on the role of pesticide adsorption beyond that observed in pure inorganic clay systems. Similar results were observed by Scrano *et al*. (2004).

Humus-clay microenvironment is a site of high biological and non biological activity and more basic information on soil herbicide interactions can be obtained by studying the microsite.

The positive and significant correlation between adsorption parameters and clay content indicated the importance of clay content in the adsorption of oxadiargyl. Also highly significant and positive correlation between adsorption parameter and clay+OC. Organic matter plays an important role in the adsorption of soil applied pesticides in soil, where organic matter content exceeds 6 per cent. But in the case of tropical and sub tropical soils with organic matter content <2%, clay content is the predominant factor in the adsorption of soil applied herbicides. The clay organo complexes are important in the adsorption of soil applied herbicides.

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Table 1. Chemical analysis data of different soils of Andhra Pradesh

S.No.	Place	pH	EC (dS m^{-1})	OC (%)	Particle size distribution (%)				Texture
	Vertisols				**Sand**	**Silt**	**Clay**	**Silt+ clay**	
V1	APRRI, Maruteru	7.62	0.35	0.73	54.4	21.6	24.0	45.6	Sandy loam
V2	RARS, Lam	7.82	0.22	0.85	55.8	11.0	33.2	44.2	Sandy clay loam
V3	Orvakallu, Kurnool	8.65	0.29	0.45	84.4	2.0	13.6	15.6	Loam sandy
V4	RARS, Nandyal	8.47	0.21	0.45	44.4	32.0	23.6	55.6	Loamy
V5	ARI, Rajendranagar	8.05	0.21	0.99	66.4	18.0	15.6	33.6	Sandy loam
V6	Gegallapuram, Ranga Reddy	7.63	0.13	0.23	66.4	8.0	25.6	33.6	Sandy clay loam
V7	Tandur, Palem	7.56	0.46	0.33	52.4	18.0	29.6	47.6	Sandy clay loam
V8	Kollapur, Palem	7.95	0.30	0.78	58.4	18.0	23.6	41.6	Sandy clay loam
V9	Bijnapally, Palem	7.56	0.33	0.69	70.4	4.0	25.6	29.6	Sandy clay loam
V10	Jagtial	7.21	0.17	0.61	13.0	13.0	35.6	48.6	Sandy loam
	Alfisols								
A1	ARS,Vuyyur	7.81	0.18	0.55	76.4	2.0	21.6	23.6	Loamy sand
A2	ARS, Darsi	6.83	0.15	0.55	81.4	6.0	13.6	19.6	Loamy sand
A3	RARS,Thirutpathi	5.49	0.11	0.61	72.4	2.0	25.6	27.6	Sandy loam
A4	ARS, Anantarajpeta	7.71	0.24	0.67	74.4	13.0	12.6	25.6	Sandy loam

S.No.	Place	pH	EC (dS m^{-1})	OC (%)	Particle size distribution (%)				Texture
	Vertisols				**Sand**	**Silt**	**Clay**	**Silt+ clay**	
A5	ARS, Ananthapur	6.66	0.11	0.30	46.4	31.0	22.6	53.6	Loamy
A6	Kodur, Kurnool	7.47	0.15	0.61	76.4	10.0	13.6	23.6	Sandy loam
A7	Yemigamur, H.khairamdi	7.59	0.17	0.75	86.4	2.0	11.6	13.6	Loamy sand
A8	Karimnagar	6.57	0.16	1.06	76.0	0.4	23.6	24	Sandy loam
A9	College Farm	7.56	0.14	0.62	72.4	4.0	23.6	27.6	Sandy clay loam
A10	Dundigal. Rangareddy	6.89	0.10	0.25	41.4	10.0	48.6	58.6	Clay
A11	Tadur, Palem	6.20	0.39	0.30	72.4	6.0	21.6	27.6	Sandy clay loam
A12	Bjnapur, Palem	6.25	0.10	0.64	68.0	4.4	27.6	32	Sandy clay loam
A13	Kollapur,Palem	6.64	0.26	0.45	77.0	5.4	17.6	23	Sandy clay loam
A14	Amadalavalasa	6.50	0.15	0.37	64.0	8.0	28.0	36	Sandy clam loam
A15	Jagtial	7.02	0.20	0.52	57.0	11.4	31.6	43.0	Sandy clay loam

Table 2. Freundlich constant for adsorption of oxadiargyl on 2 mm Vertisols and Alfisols

Soil No.	Place	OC (%)	K_f	n	K_{foc}	Longmuir constant (K_L)	Raman and Rao constant (k)
V1	APRRI, Maruteru	0.73	0.1479	0.85	20.26	1.098	0.17
V2	RARS, Lam	0.85	0.1259	0.91	14.81	1.204	0.08
V3	Orvakallu, Kurnool	0.45	0.1479	0.95	32.86	0.901	0.11
V4	RARS, Nandyal	0.45	1.000	1.00	222.22	1.204	0.17
V5	ARI, Rajendranagar	0.99	0.012	1.05	2.21	1.053	0.11
V6	Gegallapuram, Ranga Reddy	0.23	1.514	0.88	65.82	1.901	0.14
V7	Tandur, Palem	0.33	1.549	0.91	46.93	1.49	0.17
V8	Kollapur, Palem	0.78	0.398	0.80	51.02	2.27	0.08
V9	Bijnapally, Palem	0.69	1.995	0.195	289.13	3.85	0.13
V10	Jagtial	0.61	4.266	1.11	69.93	3.03	0.22
Alfisols							
A1	ARS,Vuyyur	0.55	0.25	1.10	45.67	2.05	0.11
A2	ARS, Darsi	0.55	0.11	0.70	20.00	1.20	0.13
A3	RARS, Thirutpathi	0.61	0.12	0.95	20.64	1.4	0.11
A4	ARS, Anantarajpeta	0.67	1.45	0.90	215.67	1.79	0.10

Soil No.	Place	OC (%)	K_f	n	K_{foc}	Longmuir constant (K_L)	Raman and Rao constant (k)
A5	ARS, Ananthapur	0.30	1.00	1.00	333.33	1.053	0.07
A6	Kodnur, Kurnool	0.61	0.14	0.90	23.68	1.16	0.16
A7	Yemigamur, H.khairamdi	0.75	1.00	1.00	133.33	1.098	0.09
A8	Karimnagar	1.06	2.29	0.90	216.13	2.10	0.19
A9	College Farm	0.62	1.62	0.70	261.62	1.05	0.20
A10	Dundigal, Rangareddy	0.25	2.63	0.95	105.20	1.901	0.19
A11	Tadur, Palem	0.30	0.11	0.95	36.67	1.09	0.13
A12	Bijnapally, Palem	0.64	1.90	0.91	297.65	1.901	0.12
A13	Kollapur, Palem	0.45	0.12	0.80	27.98	1.00	0.12
A14	Amadalavalasa	0.37	0.01	0.95	3.24	1.24	0.11
A15	Jagtial	0.52	0.38	0.91	73.11	2.906	0.11

Table 3. Correlation Coefficients for Freundlich (K_f), Langmuir (K_L) and Raman and Rao (K) constants with soil properties

Vertisols	**K_f**	**K_L**	**k**
pH	0.6434 * (-)	0.5984 (-)	0.4452 (-)
EC (dS m^{-1})	0.1988 (-)	0.0263 (-)	0.001
OC (%)	0.3222	0.0096	0.4256
Sand	0.2677 (-)	0.0197	0.4742 (-)
Silt	0.1392 (-)	0.3586 (-)	0.3047
Clay	0.6328 *	0.4326 *	0.4047 *
Silt + Clay	0.2677	0.0197 (-)	0.4742 *
Clay + OC	0.6231 *	0.4341	0.3908 *
Alfisols	**K_f**	**K_L**	**k**
pH	0.1227	0.1001	0.0221
EC (dS m^{-1})	0.3790 (-)	0.0924 (-)	0.1819 (-)
OC (%)	0.2900	0.2606	0.1613
Sand	0.3509 (-)	0.2917 (-)	0.0758 (-)
Silt	0.0132	0.0836 (-)	0.4034 *
Clay	0.4502 *	0.4484 *	0.4219 *
Silt + Clay	0.3479 *	0.2882 *	0.0756
Clay + OC	0.4606 *	0.4582 *	0.4288 *
All Soils	**K_f**	**K_L**	**k**
pH	0.0499 (-)	0.002 (-)	0.0717 (-)
EC (dS m^{-1})	0.1880 (-)	0.0518	0.0603 (-)
OC (%)	0.1540	0.1418	0.1065 (-)
Sand	0.3225 (-)	0.1889 (-)	0.2369 (-)
Silt	0.0164 (-)	0.1323 (-)	0.0467 (-)
Clay	0.5027 **	0.4189 *	0.4071 *
Silt + Clay	0.3211	0.1869	0.2373
Clay + OC	0.5056 **	0.4254 *	0.4070 *

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EFFECT OF BIOFERTILIZERS ON PRODUCTIVITY, PROFITABILITY AND NITROGEN USE EFFICIENCY OF LOW LAND RICE (*Oryza sativa L.*)

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ABSTRACT

A field experiment to study the effect of biofertilizers in conjunction with inorganic nitrogen on yield, nitrogen use efficiency and economics of lowland rice was carried out at Agricultural Research Station, Nellore in the Southern Agro-climatic Zone of Andhra Pradesh during two consecutive rabi seasons of 2001 and 2002. Three biofertilisers viz., Azospirillum, Azolla and blue green algae were evaluated in conjunction with 100 and 80 % recommended dose of nitrogen compared to 100 % RDN. Study revealed that higher grain and straw yield in both the years of investigation were recorded with application of Azolla along with 100 % RDN. This was on par with combination of any biofertilizer with either 100 or 80 % RDN, but was significantly superior to 100 % recommended dose of nitrogen or no nitrogen. Inoculation of Azolla along with 100 % RDN recorded highest values of N uptake, Agronomic N efficiency, Apparent N recovery and Nitrogen Harvest Index. Net returns and benefit cost ratio of low land rice due to inoculation of any one of the biofertilizers viz., Azospirillum, Azolla and BGA along with 80 % RDN were statistically similar to that of 100 % RDN without any biofertiliser inoculation, indicating a saving of 20 per cent recommended dose of N (24 kg N ha^{-1}) due to application of any one of the three biofertilizers.

To feed the ever increasing population of India there is need to increase the rice production to 128.0 million tonnes from present production of 99.15 million tonnes (Government of India, 2009-10). The productivity improvement of rice followed so far was an exponential increase in the consumption of non-renewable chemical fertilizers. The economic and environmental cost of the heavy use of chemical nitrogen as fertilizer in agriculture is a global concern. Sustainability considerations mandate that alternatives to nitrogenous fertilizers must be urgently sought. Biological nitrogen fixation, a microbiological process that converts atmospheric nitrogen into a plant usable form, offers this alternative. Nitrogen fixing systems offer an economically attractive and ecologically sound means of reducing external inputs and improving internal resources. Biofertilisers are not only part of integrated nutrients but are of low cost which is of immense help to the farming community. Among biofertilizers benefiting the rice crop production, Azospirillum, Azolla and Blue green algae (BGA) are important. Field experiments conducted in different places in India indicated the positive response of rice to Azospirillum inoculation (Rao et al., 1979) and its inoculation has shown response equivalent to 25-50 kg ha^{-1} of applied N (Hegde et al. 1991). Azolla green

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manuring or dual cropping increases the grain yield of rice on par with application of 30 kg N ha^{-1}a through fertilizer (Singh, 1992). Various studies conducted in the country have shown that BGA inoculation to transplanted rice contributed 20-30 kg N ha^{-1} per season and grain yield increase by 5-14% (Mahapatra and Jee, 1991). However, there is lack of sufficient information on the relative efficacy of these biofertilizers and extent of saving in fertilizer nitrogen to transplanted rice for southern Agro-climatic Zone of Andhra Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive rabi seasons of 2001 and 2002 at Agricultural Research Station, Nellore in the southern Agro-climatic Zone of Andhra Pradesh to study the relative efficacy of biofertilizers on growth, yield and N uptake of lowland rice. The soil of the experimental field was sandy clay loam in texture, neutral to slightly alkaline in reaction (pH 7.8), low in organic carbon (0.38 %) and available nitrogen (186.7 kg ha^{-1}), medium in available P_2O_5 (32.5 kg ha^{-1}) and K_2O (328.6 kg ha^{-1}). The experiment was laid out in randomized block design replicated thrice with eight treatments comprising 100 % recommended dose of nitrogen (RDN), combinations of three biofertilisers viz., Azospirillum, Azolla and BGA and two levels of nitrogen applied each with 100 % and 80 % RDN and absolute control (no nitrogen). The recommended dose of nitrogen @ 120 kg ha^{-1} was applied through urea in three equal splits i.e., 1/3 before transplanting, 1/3 at maximum tillering and 1/3 at panicle initiation stage. A uniform dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied to rice in the form of single super phosphate and muriate of potash. The full dose of phosphorus was applied at planting and potassium was applied in two equal splits, at planting and panicle initiation stage. Azospirillum was broadcast in the main field @ 5 kg ha^{-1} before transplanting by mixing with 25 kg powdered farmyard manure and 25 kg soil. Azolla was incorporated as green manure @ 500 kg ha^{-1} at 20 days before transplanting. Powdered BGA flakes were broadcast to the main field 10 days after transplanting @ 10 kg ha^{-1} by mixing with 25 kg powdered farmyard manure and 25 kg soil. The test variety of rice was NLR-145, a popular variety among south coastal districts of Andhra Pradesh. Thirty days old seedlings were transplanted in the main field with two seedlings per hill at 15 x 15 cm spacing. The same layout was used in both the years. Harvesting was done at physiological maturity stage and after processing, grain and straw yields were recorded. Nitrogen content in the plant samples was estimated by microkjeldhal method (Humphries, 1956). The nitrogen content of grain and straw was analysed separately and then multiplied with respective weights of grain and straw and were summed up to present N uptake at harvest. Agronomic N efficiency, Apparent N recovery (%) and Nitrogen harvest index were worked as per the following formulae.

$$\text{Agronomic N efficiency} = \frac{\text{Gain yield in treated plot} - \text{Grain yield in control plot}}{\text{kg N applied/ha.}}$$

$$\text{Apparent N recovery (\%)} = \frac{\text{N uptake in treated plot} - \text{N uptake in control plot}}{\text{kg N applied/ha.}} \times 100$$

$$\text{Nitrogen Harvest Index (NHI)} = \frac{\text{N uptake in economical yield}}{\text{N uptake in total biological yield}} \times 100$$

RESULTS AND DISCUSSION

The application of different biofertilizers exerted significant influence on grain and straw yield as well as the economics (Table 1). The application of biofertilizers along with either 100 % or 80 % recommended dose of nitrogen (RDN) increased grain and straw yield compared to 100 % RDN invariably in both the years. Application of Azolla along with 100 % RDN recorded significantly higher grain and straw yield of rice in both the years of investigation. This was however comparable with any biofertilizer with either 100 or 80 % RDN, but was significantly superior to 100 % recommended dose of nitrogen. The crop grown without the application of nitrogen produced significantly low grain and straw yields compared to any treatment. The increase in mean grain yield over two years due to Azolla, Azospirillum and BGA when applied along with 100% RDN was 10.6, 8.9 and 8.3 per cent, respectively, over 100 % RDN. The grain yield due to 80 % RDN + Azolla, Azospirillum or BGA did not differ significantly in both the years with 100 % N alone, resulting that the effect of Azolla, Azospirillum and BGA was equal to 20 per cent recommended dose of N (24 kg N ha^{-1}). Gopalaswamy et al (1997) reported 25% saving in inorganic nitrogen due to any one of Azospirillum, Azolla and BGA. Usefulness of incorporation of Azospirillum, Azolla and BGA in increasing the yield of rice and saving in fertilizer N-use was also reported by Nanjappa (2001), Mahapatra and Sharma (1998) and Sawashe et al (1985), respectively. The higher grain and straw yield of rice with conjunctive use of biofertilizers and inorganic nitrogen was due to cumulative effect of improvement in growth as well as yield attributes as a result of enhanced availability of N through nitrogen fixation by biofertilizers.

Higher mean gross returns were obtained with application of Azolla along with 100 % RDN, which was however comparable with combination of any biofertilizer with 100 % RDN, with Azolla at 80 % RDN and was significantly superior to 100 % recommended dose of

nitrogen. Higher level of grain and straw yields associated with the above mentioned treatment resulted in enhanced gross returns. Higher net returns were recorded due to application of 100 % RDN + Azolla. This was on par with any biofertilizer at 100 % RDN and with Azolla at 80 % RDN and significantly superior to 100 % RDN. The benefit cost ratio due to any of the biofertiliser at either 100 or 80 % RDN was at par and all the treatments were significantly superior over 100 % RDN. This clearly indicates the economic viability of biofertilizers to low land rice.

Nitrogen uptake in grain and straw increased due to inoculation of different biofertilizers along with either 100 % or 80 % RDN over 100 % RDN invariably in both the years of study (Table 2). Inoculation of Azolla along with 100 % RDN recorded significantly higher nitrogen uptake in grain and straw in both the years of experimentation. This was comparable with any biofertilizer with either 100 % or 80 % RDN but was significantly superior to 100 % RDN. The mean total nitrogen uptake due to Azolla, Azospirillum and BGA increased to the tune of 27.8, 19.0 and 11.0 % respectively over 100 % RDN alone. The increased nitrogen uptake in these treatments improved the agronomic N efficiency, apparent N recovery and nitrogen harvest index. Among different biofertilisers, inoculation of Azolla along with 100 % RDN recorded highest N uptake, agronomic N efficiency, apparent N recovery and nitrogen harvest index. All these values were at par among any biofetiliser either at 100 % or 80 % RDN. Favorable effects of Azolla on dry matter production and grain yield may be the reason for improvement in N uptake and efficiency of N utilization by the rice crop. Similar results were reported by Rathore et al. (1995), Naseer and Amarjit (2007).

From the present study, it can be concluded that inoculation of any one of biofertilisers viz., Azolla, Azospirillum and BGA in conjunction with 80 % recommended N through fertilizer would be sufficient for rice to get higher yield, economic returns and efficient utilization of N under low land situation of southern Agro-climatic Zone of Andhra Pradesh. This helps in reducing 20 % recommended dose of N (24 Kg N ha^{-1}) thereby saving in expenditure on nitrogen fertilizer.

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Table 1. Yield and economics of rice as influenced by biofertilisers at different levels of nitrogen.

Treatment	Grain Yield (kg ha^{-1})			Straw Yield (kg ha^{-1})		Economics		
	2001	2002	Mean	2001	2002	Gross Returns (Rs ha^{-1})	Net Returns (Rs ha^{-1})	Benefit cost ratio
T_1: Control (No nitrogen)	3347	3965	3656	3526	3974	23811	14061	2.44
T_2: 100 % RDN (@120 kg N/ha)	4279	5275	4777	4762	4868	31070	20277	2.88
T_3: 100 % RDN + *Azospirillum*	4811	5591	5201	5207	5443	33869	22926	3.09
T_4: 100 % RDN + *Azolla*	4882	5684	5283	5306	5534	34408	23365	3.12
T_5: 100 % RDN + BGA	4794	5552	5173	5210	5340	33676	22783	3.09
T_6: 80 % RDN + *Azospirillum*	4441	5477	4959	5180	5258	32364	21629	3.02
T_7: 80 % RDN + *Azolla*	4684	5514	5100	5190	5290	33220	22385	3.07
T_8: 80 % RDN + BGA	4424	5470	4947	5154	5216	32275	21590	3.02
SE∂	180	139	170.1	186	198	781	694	0.09
CD at 5 %	286	298	364	398	423	1672	1485	0.19

Cost of produce: Grain: Rs.6.00 kg $^{-1}$, straw Rs.0.50 kg^{-1}.

Cost of urea: Rs.200 per 50 kg bag.

Cost of inoculation biofertilizers per hectare: *Azospirillum* Rs.150 ha^{-1}, *Azolla* Rs.250 ha $^{-1}$, BGA Rs.100 ha^{-1}.

Table 2. Nitrogen uptake and use efficiency of rice as influenced by biofertilisers at different levels of nitrogen

Treatments	Nitrogen uptake (kg ha^{-1})							Nitrogen use efficiency		
	2001			2002			Mean	Agronomic Nitrogen efficiency	Apparent Nitrogen recovery	Nitrogen Harvest Index
	Grain	Straw	Total	Grain	Straw	Total				
T_1: Control (No nitrogen)	28.3	29.7	58.0	34.1	34.1	68.2	63.1	--	--	49.5
T_2: 100 % RDN (@120 kg N/ha)	38.9	42.4	81.3	51.9	44.6	96.5	88.9	9.3	21.5	51.1
T_3: 100 % RDN + *Azospirillum*	52.9	45.5	98.4	64.9	48.3	113.2	105.8	12.9	35.6	55.7
T_4: 100 % RDN + *Azolla*	57.4	47.5	104.9	71.8	50.5	122.3	113.6	13.5	42.1	56.9
T_5: 100 % RDN + BGA	50.8	42.6	93.4	59.4	44.6	104.0	98.7	12.6	29.7	55.8
T_6: 80 % RDN + *Azospirillum*	45.6	45.1	90.7	56.8	46.7	103.5	97.1	13.6	35.4	52.7
T_7: 80 % RDN + *Azolla*	48.3	47.3	95.6	64.3	49.5	113.8	104.7	15.0	43.3	53.8
T_8: 80 % RDN + BGA	43.2	42.9	86.1	54.0	44.7	98.7	92.4	13.5	30.5	52.6
SE∂	4.4	3.9	4.5	3.7	3.0	3.0	4.1	--	--	--
CD at 5 %	9.4	8.4	9.5	7.8	6.4	6.4	8.8	--	--	--

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COMBINING ABILITY STUDIES FOR GRAIN YIELD AND ITS COMPONENTS IN MAIZE (*Zea mays* L.)

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ABSTRACT

Combining ability studies were carried out for yield and yield components in 28 single cross maize hybrids produced by crossing eight parents in a diallel fashion excluding reciprocals. The hybrids along with parents and check were evaluated during *rabi*, 2007-08. The results of combining ability analysis revealed significant mean squares due to general and specific combining ability indicating that both additive and non-additive gene actions were important in the inheritance of the characters studied. Variances due to SCA were larger than GCA for all the characters indicating the predominance of non- additive gene action in expression of various traits. Among the parents BML-15 and CM-119 the best general combiners for grain yield and most of the yield contributing characters. Among hybrids, BML-15 x CM-209, CM-132 x CM-209, CM-209 x CM-119, CM-210 x CM-119 and CM-132 x CM-119 were the best specific combiners for grain yield. Most of the crosses which recorded high *sca* effects involved at least one parent with desirable *gca* effect for that trait.

Maize (*Zea mays* L.) is one of the most important cereal crops and occupies a prominent position in global agriculture. The commercial production of hybrids depends upon two factors *viz.,* the behaviour of a line itself and the behaviour of line in hybrid combinations. The behaviour of a line in hybrid combination is assessed through the estimation of general combining ability (*gca*) and specific combining ability (*sca*) effects. Combining ability of the inbred lines is the ultimate factor for determining future usefulness of the lines and helps in classifying inbred lines relative to their cross combinations. Combining ability analysis provides this information and is frequently used by plant breeders as a tool to evaluate the prepotency of cultures to be used in breeding programme and to assess the gene action involved in various characters so as to design an appropriate and efficient breeding method. Hence, an attempt was made in the present investigation to estimate the combining ability for important yield components in maize.

MATERIALS AND METHODS

Eight elite inbred lines of maize *viz.,* BML-15, BML-13, BML-10, CM-132, CM-133, CM-210, CM-209 and CM-119 were selected and crossed in diallel fashion excluding reciprocals during *kharif*, 2007. The resulting 28 crosses along with parents and a standard check BH 1576 were evaluated in randomized block design replicated thrice, during *rabi*, 2007-08 at

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Agricultural College Farm, Rajendranagar, Hyderabad. Each entry was represented by a single row of 5 m length. The spacing of 75 x 25 cm was followed between and within the rows. The data were recorded on yield and yield contributing traits *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, days to 50% maturity, plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100 grain weight and grain yield. The data obtained from F_1s and parents were analyzed as per Method II (F_1s + parents) and Model -I (fixed effect) of Griffing (1956) for combining ability.

RESULTS AND DISCUSSION

The analysis of variance of parents and hybrids for yield and yield contributing characters are presented in Table 1. The mean sum of squares was highly significant for all the traits suggesting substantial variability in the material. The mean sum of squares for replications was significant for plant height, ear height and number of kernel rows per ear indicating the influence of uncontrolled effects.

The magnitude of variance due to SCA was larger than GCA for all the characters indicating the predominance of non- additive gene action in expression of various traits (Table 2). This was supported by less than one ratio of $\acute{o}^2$ GCA: $\acute{o}^2$ SCA. Similar findings were reported earlier by Jha and Khehra (1993) and Farzana *et al*., (2007).

The *gca* effects (Table 3) revealed that the inbred line CM-119 was the best general combiner for yield and all the yield contributing characters except ear height and number of kernel rows per ear. The inbred BML-15 was also the best general combiner for yield and all yield contributing characters except for number of kernel rows per ear and kernels per row. Selection of these parents will be effective in synthetic or composite breeding programme. Dass *et al.,* (1997) reported that at least one good general combiner is essential for getting a good hybrid combination. The parents, BML-10 and CM-209 had high *gca* effects for earliness *i.e.*, days to 50% tasseling, days to 50% silking and days to 50% maturity. Significant *gca* effects were observed in BML-15 and CM- 119 for ear length; BML-15 and CM- 132 for ear girth; CM-132 and CM-209 for number of kernel rows per ear; CM-119 and CM-210 for number of kernels per row; BML-15 and BML-10 for 100 grain weight. Aguiar *et al*. (2003) reported that *gca* effects were significant for all traits.

The good combiners – BML-15 and CM-119 for grain yield also had good combining ability for characters *viz.,* ear length, ear girth and hundred grain weight.

The *sca* effects (Table 4) revealed that the crosses BML-15 x CM-209,

CM-132 x CM-209, BML-13 x CM-210 and CM-209 x CM-119 exhibited highest magnitude of positively significant *sca* effects for grain yield and yield contributing characters. The *per se* performance of these crosses was also good.

The cross combinations BML-15 x BML-13, BML-15 x BML-10 and CM-133 x CM-210 were identified as best combiners for ear length, CM-133 x CM-210 for ear girth, BML-13 x CM-132 for number of kernel rows per ear, BML-15 x BML-10 and CM-132 x CM-210 for number of kernels per row, CM-132 x CM-210, BML-15 x CM-209 and BML-15 x CM-210 for 100-grain weight were identified as the best combiners for the respective characters as they have significant *sca* effect. Gautam (2003) reported significant *sca* effects for grain yield, plant height, ear length, days to maturity and 100 grain weight.

Based on these investigations it can be concluded that the inbreds BML-15 and CM-119 can be used as parents for high yielding single cross hybrids. The identified five superior crosses *viz.,* BML-15 x CM-209, CM-132 x CM-209, CM-209 x CM-119, CM-210 x CM-119 and CM-132 x CM-119 could be used for immediate exploitation as well as population improvement programme.

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Table 1. Analysis of variance for grain yield and its components in maize

Source of variation	d.f	Mean of sum of squares										
		Days to 50% tasseling	Days to 50 % silking	Days to 50% maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 Grain weight	Grain yield/ plant
Replications	2	0.26	0.12	0.19	1100.39**	100.26**	2.18	0.15	1.80*	6.02	0.60	159.17
Genotypes	35	59.75**	63.02**	77.49**	5425.08**	210.11**	8.58**	6.24**	4.90*	55.74**	93.18**	4174.52**
Error	70	2.55	3.06	6.66	213.80	19.14	0.69	0.24	0.50	2.93	0.57	66.35

Significant at 5 per cent level; ** Significant at 1 per cent level.

Table 2. Combining ability analysis of grain yield and its components

Source	d.f	Days to 50% tasseling	Days to 50 % silking	Days to 50% maturity	Plant Height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 Grain weight	Grain yield per plant
gca	7	49.21**	47.41**	48.69**	2766.04**	109.04**	2.00	1.29	1.85	29.64**	57.26**	972.37**
sca	28	12.6**	14.41**	20.12**	1568.94**	60.29**	3.07**	2.28**	1.58	15.81**	24.51**	1496.29**
Error	70	0.85	1.02	2.22	71.27	6.38	0.23	0.08	0.17	0.98	0.19	22.12
^{2}**GCA**		3.66	3.30	2.86	119.71	4.88	-0.11	-0.10	0.03	1.38	3.27	-52.39
^{2} **SCA**		11.74	13.25	17.90	1497.67	53.91	2.84	2.19	1.41	14.84	24.32	1474.17
^{2}**GCA/** ^{2} **SCA**		0.31	0.25	0.16	0.08	0.09	-0.04	-0.05	0.02	0.09	0.13	-0.04

* Significant at 5 per cent level; ** Significant at 1 per cent level.

Table 3. General combining ability effects for grain yield and its components in 8 elite maize inbreds

Parents	Days to 50% tasseling	Days to 50 % silking	Days to 50% maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 Grain weight	Grain yield per plant
BML-15	1.77**	1.31**	1.16**	25.52**	7.02**	0.71**	0.45**	-0.61**	-0.12	4.53**	5.62**
BML-13	0.03	0.40	0.96*	-28.19**	-4.08**	-0.72**	-0.51**	-0.20	-3.26**	0.28*	-3.36**
BML-10	-4.87**	-4.79**	-4.78**	-10.8**	-1.35	-0.11	0.17	-0.13	-0.19	1.67**	-4.93**
CM-132	1.33**	1.41**	1.73**	-4.22	-1.99**	0.25	0.39**	0.72**	0.49	-0.62**	1.02
CM-133	1.43**	1.34**	1.09*	-4.38	-1.36	-0.31*	-0.36**	-0.37**	-1.08**	-0.66**	-2.81*
CM-210	0.67*	0.88**	0.69	5.37*	0.84	0.05	-0.02	0.28*	1.00	-2.78**	-8.69**
CM-209	-1.47**	-1.63**	-1.84**	-0.81	-0.42	-0.25	-0.32**	0.36**	0.41	-2.82**	-8.33**
CM-119	1.10**	1.08**	0.99*	17.52**	1.35	0.39**	0.20*	-0.05	2.74**	0.41**	21.45**
Range	-4.87 - 1.77	-4.79 - 1.41	-4.78 - 1.73	-28.19 - 25.52	-4.08 - 7.02	-0.72 - 0.71	-0.51 - 0.45	-0.61 - 0.72	-3.26 - 2.74	-2.82 - 4.53	-8.69 - 21.45
SE (gi)	0.27	0.3	0.44	2.50	0.75	0.14	0.08	0.12	0.29	0.13	1.39
SE (gi-gj)	0.41	0.45	0.67	3.78	1.13	0.22	0.13	0.18	0.44	0.2	2.10

* Significant at 5 per cent level; ** Significant at 1 per cent level.

Table 4. Specific combining ability effects for grain yield and its components in 28 single cross maize hybrids

Crosses	Days to 50% tasseling	Days to 50 % silking	Days 50% maturity	Plant height (cm)	Ear Height (cm)	Ear Length (cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 Grain weight	Grain yield per plant
BML-15 x BML-13	0.79	-0.56	-1.76	52.6**	8.52**	3.04**	1.11**	0.17	2.52**	2.21**	18.60**
BML-15 x BML-10	-1.31	-1.03	0.31	48.06**	12.11**	2.28**	0.82**	0.36	5.92**	1.55**	39.49**
BML-15 x CM-132	1.83*	1.44	1.81	5.83	2.86	-0.74	0.82**	-1.70**	-3.63**	-5.70**	-40.82**
BML-15 x CM-133	0.39	-1.49	-4.22**	32.2**	3.27	-0.6	-0.71**	-0.68*	1.72*	4.54**	33.45**
BML-15 x CM-210	-4.17**	-4.69**	-6.16**	28.91**	3.79	-0.53	-1.10**	-0.21	-0.61	7.28**	23.67**
BML-15 x CM-209	-0.04	1.14	2.71*	18.30*	3.33	0.26	1.46**	1.09**	2.31**	8.02**	64.47**
BML-15 x CM-119	1.73*	2.77**	2.54*	-2.45	-6.31**	-0.64	-0.95**	-0.14	-4.67**	0.19	-24.21**
BML-13 x BML-10	-1.91*	-2.46**	-4.16**	0.26	-2.29	2.87**	1.32**	-0.3	1.61	2.26**	17.72**
BML-13 x CM-132	-5.77**	-5.33**	-4.32**	-27.75**	-5.37*	0.38	1.09**	2.38**	2.62**	3.43**	30.57**
BML-13 x CM-133	0.13	0.07	-0.69	-31.42**	-10.28**	-1.47**	0.64**	0.01	-2.79**	0.32	4.09
BML-13 x CM-210	0.23	1.54	3.71**	27.39**	7.08**	0.09	0.21	-0.42	0.59	-0.82*	42.48**
BML-13 x CM-209	2.36**	2.04**	1.91	-48.61**	-11.62**	-2.10**	-1.70**	0.51	0.45	-2.23**	-9.3**
BML-13 x CM-119	-1.54*	-1.99**	-2.26	31.51**	6.86**	0.09	-0.24	1.19**	-4.55**	-2.22**	-0.8
BML-10 x CM-132	2.79**	2.54**	1.74	-0.08	0.1	0.58	0.24	0.54	4.76**	3.46**	27.83**
BML-10 x CM-133	0.03	-0.06	0.38	20.68**	-0.76	1.29**	1.50**	1.14**	-2.31**	2.63**	14.72**
BML-10 x CM-210	-0.21	-0.93	-1.89	-6.98	2.48	-0.13	0.03	-0.87*	2.46**	-3.61**	-29.41**
BML-10 x CM-209	-6.41**	-7.43**	-10.02**	-17.69*	-5.22*	-0.3	0.81**	-0.99**	-1.08	-2.79**	-31.69**
BML-10 x CM-119	-0.97	-0.79	-0.19	22.51**	3.94	0.53	0.96**	-0.76*	4.07**	-1.01**	14.15**

Contd…table 4

CM-132 x CM-133	-1.17	-0.93	-0.46	2.08	-2.42	1.35**	1.92**	-0.26	3.29**	-4.00**	2.13
CM-132 x CM-210	1.26	2.21**	2.61*	50.42**	-0.3	0.64	0.12	-1.67**	4.85**	10.21**	22.00**
CM-132 x CM-209	-1.61*	-1.29	-0.86	36.65**	13.7**	2.75**	1.79**	0.09	4.14**	2.22**	52.58**
CM-133 x CM-209	0.96	1.11	-0.22	28.55**	5.78**	0.54	0.73**	-1.36**	-1.05	-1.58**	2.58
CM-133 x CM-119	-4.61**	-4.93**	-4.39**	1.89	5.44*	-1.41**	-0.28	-0.19	-3.64**	-8.53**	-36.04**
CM-210 x CM-209	1.06	0.91	1.51	21.56**	7.92**	0.19	0.93**	2.01**	-2.91**	-2.77**	-4.09
CM-210 x CM-119	-8.84**	-9.13**	-9.66**	-2.58	-3.89	0.48	0.75**	1.53**	2.73**	-4.39**	26.04**
CM-209 x CM-119	-2.71**	-2.63**	-1.79	6.69	-1.37	-0.46	-1.37**	1.91**	4.36**	6.42**	39.59**
SE (Sij)	7.00	7.67	11.30	64.05	2.30	3.65	2.17	3.10	7.50	0.26	35.68
SE (Sij-Sij)	10.36	11.34	16.73	94.76	2.78	5.40	3.21	4.58	11.10	0.31	52.79
Range	-8.84 -	-9.13 -	-10.02 -	-48.61 -	-11.62 -	-2.1 -	-1.70 -	-1.7 -	-4.67 -	-8.53 -	-40.82 -
	3.49	4.67	6.98	52.6	13.7	3.2	2.05	2.38	5.92	10.21	64.47
CM-133 x CM-209	0.96	1.11	-0.22	28.55**	5.78**	0.54	0.73**	-1.36**	-1.05	-1.58**	2.58
CM-133 x CM-119	-4.61**	-4.93**	-4.39**	1.89	5.44*	-1.41**	-0.28	-0.19	-3.64**	-8.53**	-36.04**
CM-210 x CM-209	1.06	0.91	1.51	21.56**	7.92**	0.19	0.93**	2.01**	-2.91**	-2.77**	-4.09
CM-210 x CM-119	-8.84**	-9.13**	-9.66**	-2.58	-3.89	0.48	0.75**	1.53**	2.73**	-4.39**	26.04**
CM-209 x CM-119	-2.71**	-2.63**	-1.79	6.69	-1.37	-0.46	-1.37**	1.91**	4.36**	6.42**	39.59**

* Significant at 5 per cent level; ** Significant at 1 per cent level.

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EFFECT OF INTERCROPPING ON GROWTH, NUTRIENT UPTAKE AND SEED YIELD OF CASTOR (*Ricinus communis* L.) GROWN UNDER RAINFED CONDITIONS

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ABSTRACT

A field experiment was conducted at the National Academy of Agricultural Research Management, Hyderabad during *kharif* 2007and 2008. Castor variety 'Kranti' was grown in two planting patterns viz., uniform row spacing of 90 cm and paired row spacing of 120/60 cm with a common intra row spacing of 20 cm. They were evaluated in sole and intercropping systems. One row each of sorghum and sunflower and two rows each of pearlmillet, greengram, blackgram and soybean were flanked between the uniform rows and an additional intercrop row was interspersed between the paired rows of castor. The results showed that the plant height, phytomass per plant and uptake of N P K by castor did not differ significantly by planting the crop in uniform row spacing of 90 cm or paired row planting at 120/60 cm. The intercropping of blackgram did not reduce the vegetative growth, uptake of N P K and seed yield of castor. Sorghum, pearlmillet, greengram, soybean and sunflower were highly competitive intercrops. They reduced the plant height, phytomass accumulation, nutrient uptake and seed yield of castor.

Castor (*Ricinus communis* L.)is generally grown under extremely neglected conditions in wide rows and in soils of coarse texture and poor fertility status under undependable quantity of rain with erratic distribution during its growing season. Wider fluctuations in the amount of rainfall and its distribution received through south-west monsoon during the crop growth period results in wide variation in productivity.

The crop has hardy growth habit with deep tap root system. It is a long duration crop with slow growth habit in the initial stages. These features offer a potential scope to intercrop relatively short duration and quick growing crops to exploit the land resources more efficiently. The intercropping of compatible crops is one possible way to minimize the risk of complete loss for sustenance of peasants. There was a need to find out suitable crop(s) which were compatible and suitable for intercropping with castor for minimizing the risk and enhancing the productivity. Hence, a field experiment was conducted to test crops of diverse growth habit by intercropping with castor under rainfed conditions.

MATERIALS AND METHODS

The investigation was carried out at the Agricultural Farm, National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad. In the National Agricultural Research Project Zonation, it comes under the Southern Telangana region of

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Andhra Pradesh. The soil was sandy clay loam in texture, slightly alkaline in reaction, low in available nitrogen (142 N kg ha^{-1}), and phosphorus (9.96 kg P ha^{-1}) and rich in potassium (341 kg K ha^{-1}). The soil had a tendency for crust formation.

The experiment was laid out in randomized block design with three replications. There were 14 treatments. They involved two planting patterns of castor in uniform row spacing of 90 cm and paired row planting at 120/60 cm. Spacing between the plants within the rows was 20 cm in both the planting patterns. Castor variety '*Kranti*'was grown as a sole crop in both the patterns and intercropped with sorghum, pearl millet, green gram, black gram, soybean and sunflower. One row of sorghum and sunflower but two rows of pearlmillet, greengram, blackgram, and soybean were intercropped between two rows of castor in uniform row planting. Two rows of sorghum and sunflower and three rows of pearlmillet, greengram, blackgram and soybean were intercropped between the paired rows of castor. Each of the intercrop was also raised as sole crop in plots adjacent to the experiment for their use in the calculation of land equivalent ratios. The crops were grown completely under rainfed conditions during both the years. There was a rainfall of 361.2 mm distributed in 14 weeks during the crop growing period in 2007. A higher amount of 843.9 mm rainfall was distributed over a period of 11 weeks during the second year. Castor was fertilized with 80:60:40 kg N, P_2O_5 and K_2O / ha in sole and intercropped systems. The intercrops were also fertilized in proportion to their population. The entire dose of fertilizer was applied as basal for all the crops except castor, sorghum, pearl millet and sunflower for which nitrogenous fertilizer was applied in two splits viz. half as basal and remaining half at 35 days after sowing. All the recommended agronomical practices were followed and crops were raised completely as rainfed.

RESULTS AND DISCUSSION

Crop growth

The data on mean plant height of castor in response to planting pattern and intercropping for the two years is presented in table 1. The results showed that the plant height of castor was on par in paired row planting at 120 – 60/ 20 cm and conventional uniform row spacing of 90 x 20 cm. The plant height of castor intercropped with green gram or black gram was on par with sole crop during both the years. Castor intercropped with soybean attained plant height on par with the sole crop only during the first year. The intercropped sorghum, pearlmillet or sunflower significantly reduced the plant height of castor consistently during both the years.

The phytomass accumulation per plant in castor did not differ significantly due to paired row planting compared to the uniform row planting. But this variable was greatly influenced by the intercrop component (Table 1). Among the different intercrops, sorghum,

pearl millet, green gram and sunflower significantly reduced the phytomass per plant of castor consistently during both the years. The intercropped soybean significantly reduced the phytomass of castor only in the second year. The phytomass accumulation of castor intercropped with black gram was on par with the sole castor during both the years.

The mean plant height of castor and its phytomass production reduced significantly by the intercropping of sorghum, pearlmillet or sunflower consistently during the two years as these crops were highly aggressive to impart severe competition for resources with castor during its reproductive development phase, until it reached physiological maturity.

Black gram and green gram served as ephemerals to complete their lifecycle by the time castor attained the reproductive growth phase. They flowered in one month and commenced pod formation at about 40 to 45 days at a time when castor was in juvenile phase of its growth. The intercropped blackgram grew less vigorously with stunted growth during both the years. Hence blackgram did not affect the growth of castor. However, intercropped greengram grew more vigorously and as a result competed with castor for the natural and applied resources and affected the phytomass accumulation both during 2007 and 2008. Soybean competed with castor more vigorously during the second year and reduced the plant height and phytomass accumulation of castor. Inferences on such harmful effects in reducing the growth or dry matter production of castor by intercropping legumes like cowpea, greengram, groundnut, cluster bean or soybean were also reported by Gangasaran and Giri (1983), Al-Bakry and Saran (1985), Venkateswarlu and Balasubramanian (1990), Srilatha *et al.* (2002) and Padmavathi and Raghavaiah (2004).

Seed yield of castor

The seed yield of castor was not affected by intercropping blackgram both during 2007 and 2008 (Table 1) but castor produced significantly less seed yield by intercropping sorghum, pearlmillet, greengram, soybean or sunflower. Such drastic competitive effects in reduction of castor yield due to intercropping of sorghum (Patel *et al*., 1989) and of greengram and soybean (Gupta and Rathore, 1993) were documented in the literature. However, no significant reduction in castor yield due to intercropping with blackgram or greengram or soybean was reported by Srilatha *et al*. (2002).

Nutrient uptake

The mean uptake of nitrogen by castor was not influenced by growing it in paired rows than in the conventional uniform row spacing both during 2007 and 2008 (Table 2). The intercropping of sorghum, pearlmillet, greengram or sunflower reduced the uptake of nitrogen by castor at harvest consistently during both the years. The intercropped soybean reduced

the nitrogen uptake by castor only during first year. The intercropped blackgram alone did not inflict a serious limitation to castor in the removal of this nutrient from soil during 2007 and 2008.

The uptake of phosphorus by castor did not vary significantly by changing its planting pattern from the uniform row spacing of 90 cm to the paired row orientation of 120 / 60 cm during the two years (Table 2). The uptake of phosphorus by castor was remarkably influenced by different intercropped components and the seasonal variability during the two years. A distinct competitive effect of intercropping sorghum, pearlmillet, greengram, soybean or sunflower in reducing the uptake of P by castor at harvest was recorded during both the years. However, intercropped blackgram did not exert significant and negative influence on the uptake of P by castor in either of the two years.

The uptake of K by castor did not change significantly due to a change in the planting pattern from uniform to paired rows (Table 2). The intercrops exercised substantial influence on castor in the uptake of this nutrient during the two years. Sorghum and pearl millet were the most competitive intercrops in reducing the uptake of K by castor significantly during both the years. The intercropped greengram reduced the uptake of K by castor at harvest only during 2007 while soybean and sunflower reduced it during the second year but castor intercropped with blackgram removed K on par with sole crop invariably both during 2007 and 2008.

Sorghum, pearlmillet and sunflower have competed with castor more aggressively for nutrients thereby reducing its phytomass per plant and also the uptake of N, P and K by castor. Greengram and soybean also competed with castor for nutrients but the results are not consistent for the two years. However blackgram alone did not impart severe competition for nutrients with castor consistently under varying climatic conditions. This might be due to less aggressive growth habit of blackgram in addition to its short duration. The natural and applied resources might have been easily available to the castor crop and the latter performed as better as sole crop during both the years.

The more serious effect on the performance of castor in terms of plant height, phytomass accumulation per plant, seed yield and uptake of N P K in the second than in the first year could probably be attributed to the continuous wet spell of heavy rains from sowing until 50 days. This condition might have created anoxia to the roots by clogging the micro pores of the soil and holding surplus moisture of much higher magnitude with inadequate drainage than in the first year. This condition arrested the crop growth. Similar findings were reported by Padmavathi and Raghavaiah (2004) that the moisture stress experienced during crop growth adversely affected the vegetative and reproductive stages resulting in low yields

in castor and intercrops. It was also reported that the waterlogged soils hampered the crop growth of castor seriously.

The results revealed that among the six crops tested, blackgram was more compatible for intercropping in castor as it did not affect the latter adversely in terms of growth, nutrient uptake and seed yield of castor during varying climatic conditions.

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Table 1. Plant height, phytomass per plant and seed yield of castor at harvest as influenced by planting pattern and intercrops

Treatment	*Kharif* 2007			*Kharif* 2008		
	Plant height (cm)	Phytomass (g plant^{-1})	Seed yield (kg ha^{-1})	Plant height (cm)	Phytomass (g plant^{-1})	Seed yield (kg ha^{-1})
Planting pattern						
Uniform rows	189.4	104.9	625	103.9	61.2	406
Paired rows	194.2	106.2	631	115.7	62.0	415
SE±	12.5	7.1	23	5.1	3.4	20
CD at 5%	NS	NS	NS	10.4	NS	NS
Intercropping						
Sole castor	226.5	134.3	897	129.2	78.8	600
Castor + Sorghum	156.2	95.0	477	108.8	55.8	310
Castor + Pearlmillet	145.3	79.7	338	84.3	43.9	221
Castor + Greengram	183.4	101.5	484	120.1	63.1	435
Castor + Blackgram	235.1	110.4	878	129.0	76.0	571
Castor + Soybean	213.6	116.7	702	102.7	58.0	432
Castor + Sunflower	182.4	101.2	620	94.5	55.8	305
SE±	23.5	13.3	43	9.5	6.3	38
CD at 5%	48.2	27.3	89	19.5	13.0	78
Interaction						
SE±	33.2	18.8	61	13.4	9.0	54
CD at 5%	NS	NS	NS	NS	NS	NS

Table 2. Uptake of nitrogen, phosphorous and potassium by castor at harvest as influenced by planting pattern and intercrops

Treatment	*Kharif* 2007			*Kharif* 2008		
	Uptake of N (kg ha^{-1})	Uptake of P (kg ha^{-1})	Uptake of K (kg ha^{-1})	Uptake of N (kg ha^{-1})	Uptake of P (kg ha^{-1})	Uptake of K (kg ha^{-1})
Planting pattern						
Uniform rows	87.4	13.70	66.1	46.06	6.09	45.13
Paired rows	88.5	13.71	69.2	46.61	6.63	45.36
SE±	7.3	1.09	5.9	3.32	0.66	3.30
CD at 5%	NS	NS	NS	NS	NS	NS
Intercropping						
Sole castor	119.3	18.84	89.1	62.47	9.48	55.54
Castor + Sorghum	75.4	11.35	56.9	39.76	5.28	36.80
Castor + Pearlmillet	61.1	9.43	49.5	31.75	4.39	28.07
Castor + Greengram	84.0	12.89	65.3	46.20	5.78	49.50
Castor + Blackgram	98.7	15.18	71.4	56.75	8.26	63.76
Castor + Soybean	93.7	15.38	72.4	45.31	5.76	42.13
Castor + Sunflower	83.3	12.87	69.1	42.12	5.57	40.92
SE±	13.7	2.05	11.1	6.20	1.24	6.18
CD at 5%	28.1	4.21	22.8	12.75	2.55	12.70
Interaction						
SE±	19.3	2.90	15.7	8.77	1.75	8.74
CD at 5%	NS	NS	NS	NS	NS	NS

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PERFORMANCE OF MAIZE (*Zea mays* L.) AND SUNFLOWER (*Helianthus annuus* L.) UNDER DIFFERENT SOWING DATES IN RICE FALLOWS

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ABSTRACT

Field experiments were conducted during winter 2007-08 and 2008-09 in clay loam soils of rice fallows to find out the optimum date of sowing of maize and sunflower crops at Regional Agricultural Research Station, Warangal, Andhra Pradesh under no till condition. It was found that maize crop sown from 15th November to 15th December gave at par yields and reduced significantly thereafter. In sunflower, the seed yield was significantly reduced in each delayed sowing by 15 days from 15th November. Higher net return (Rs ha^{-1}) was obtained when either of the crops was sown from 15th November to 30th November. Maize crop registered significantly superior yields than sunflower at all the dates of sowing.

Conservation farming systems play a major role in sustainable agricultural production, world wide. In Andhra Pradesh, rice is cultivated in an area of 4.4 M ha, of which 4.2 M ha is transplanted in the puddled field, while the rest is sown direct. In the coastal region, farmers used to cultivate black gram as relay crop during winter in rice fallows. Due to severe YMV infestation during the second half of this decade, the crop was devastated, compelling the farmers to dispense with. Sowing maize between the rice stubbles under no till condition proved to be a boon in the Western Delta. Since then, realizing the advantages of no till cultivation *viz*., saving on land preparation, irrigation and energy, advancement of time of sowing of the next crop by 2-3 weeks (Ram *et al*., 2006 and Mohammad, 2009), there was a surge in the interest of the farmers in zero tillage cultivation of maize and extended even to the areas of rice-rice cropping system. In addition, Zero tillage has a direct mitigation effect as it converts the green house gases like CO_2 into O_2 in the atmosphere and carbon in the soil and enriches soil organic matter (Venkateswarlu and Shankar, 2009). Apart from maize, sunflower crop was also identified as a successful and profitable sequential crop in rice fallows of Telangana region of Andhra Pradesh (Kumar *et al.*, 2005).

Usually rice crop is harvested between October and December. The interaction of harvesting time of rainy season rice, field moisture condition and temperature at and after harvest of rice determines the time of sowing and success of a winter crop (Kalita *et al*., 2005). Maize and sunflower matures in 100-120 days unlike black gram which matures in 80-

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90 days. Therefore, the time of sowing is critical to match with the availability of water until the grain filling stage (kg ha^{-1}) (Mohammad, 2009). Keeping these factors in view, the present investigation was undertaken to study the performance of maize and sunflower at different dates of sowing in rice fallows under no till condition matching with the harvesting of the previous rice crop.

MATERIALS AND METHODS

Field experiments were conducted during winter 2007-08 and 2008-09 in rice fallows under no till conditions at the Regional Agricultural Research Station, Warangal, Andhra Pradesh. The soil was clay loam with a pH of 7.4 and EC of 0.2 d Sm^{-1}, low in organic carbon (0.25 %) and available nitrogen (252 kg/ha), medium in available P (28 kg P_2O_5/ha) and high in available K (391 kg K_2O/ha). The experiment was laid out in a Randomized Block Design comprising of 8 treatment combinations of two crops *i.e.,* maize and sunflower and four dates of sowing *i.e.*, 15th November, 30th November, 15th December and 30th December. The treatments were replicated thrice and statistically analysed using factorial concept.

The rainy season rice was sown under puddling during the first week of July and harvested during the first fortnight of November. Five days before harvesting of rice, a light irrigation was given to facilitate good germination and maize or sunflower were dibbled @ one seed/hill in the rice fallows on the respective dates. Maize hybrid, Dekalb Super 900 M and sunflower hybrid, Sunbest 99 were used for the study. All the other recommended package of practices were followed. A rainfall of 150.5 mm was received during 2007-08 in 8 rainy days and 3.6 mm was received during 2008-09 in one rainy day throughout the crop growth period.

For the convenience of comparison, the seed yield of sunflower was converted into maize equivalent yield (MEY) by converting the yield into economic value based on the prevailing prices at the local regulated market during both the years and statistically analyzed. Net return (Rs ha^{-1}) was calculated by deducting the cost of cultivation (Rs ha^{-1}) from the gross return (Rs ha^{-1}).

RESULTS AND DISCUSSION

Yield attributes and yield of maize

The maize crop sown on 15th December registered higher number of kernels/cob, kernel weight/cob (g), dry weight at harvest (g/plant) and grain yield (kg ha^{-1}) during 2007-08 (Table 1). But during 2008-09, the maize crop sown on 15th November registered higher yield attributes and yield than at the other dates. However, the test weight (g) remained unaffected with the date of sowing during both the years. The duration of the crop was extended by 4-6

days at delayed sowing i.e., on 30th December compared to sowing on 15th November during 2007-08. This might be due to the slow germination and growth during the early stages consequent to the low minimum temperatures prevailed during December-January.

Such significant differences in yield attributes and yield could be ascribed to variation in climatic characters, especially relative humidity, maximum and minimum ambient temperatures (Dass *et al*., 2005). Fakorede and Opeke (1985) concluded that maximum and minimum relative humidity demonstrated negative relationships with maize yield. Pal *et al.* (1996) also reported a reduction of 37.5 kg ha^{-1} day^{-1} in grain yield of wheat due to delayed sowing in rice fallows.

Yield attributes and yield of sunflower

Sowing of sunflower crop early i.e., on 15th November registered higher seed weight/ plant (g), number of filled seeds/head and seed yield (kg ha^{-1}) (Table 2) and less chaffyness during both the years of study than the later dates of sowing but the test weight (g) and the crop duration remained more or less same with different dates of sowing.

De la Vega and Hall (2002) found that sunflower yields were strongly reduced when normal sowing dates were delayed from November to December months in Argentina. Similar findings were reported by Kalita *et al.* (2005) and Hari *et al. (*2007).

Maize equivalent yield

The mean data for two years revealed that maize crop recorded significantly higher equivalent yield (kg ha^{-1}) than sunflower, irrespective of the dates of sowing (Table 3). Among the four dates, sowing of either of the crops from 15th to 30th November was at par statistically while the latter date was also at par with 15th December. Delay in sowing beyond 15th December substantially reduced the yield. Maize crop sown from 15th November to 15th December was statistically equal. However, in sunflower, delay in sowing by 15 days each time from 15th November significantly reduced the equivalent yield. In both the crops, a remarkable yield loss was observed (32 % in maize and 28 % in sunflower) when sown later than 15th December. These findings are in conformity with Andrade (1995). The reduction in yield in delayed sowing was due to decrease in number of grains/cob and grain weight.

Accumulated growing degree days (GDD) during vegetative, entire growth period and grain filling period were reported to have significant positive correlation with grain yield in wheat (Khan *et al*., 2010). Kucharik (2008) quantified the relationships among the maize yields, planting dates and monthly climate variables in 12 U.S States. In six of the 12 States, a significant relationship ($P<0.05$) existed between first difference of planting dates and yields while yield increases between 0.06 and 0.14 kg ha^{-1} were attributed to each additional day of earlier planting.

Net return

Sowing of either of the crops on 15th November was significantly more profitable with sowing on 15th December but was at par with sowing on 30th November. Delayed sowing beyond 15th December drastically reduced the net return/ha (Table 3). Between the two crops, growing maize crop registered higher net return than sunflower. The interaction effect between the crops and dates of sowing revealed that sowing of maize on 15th December gave higher net return significantly superior to the rest of the dates of sowing, while sunflower crop sown on 15th November was profitable than all the delayed sowings.

Thus, the findings indicated that maize crop can be sown from 15th November to 15th December, while sunflower is profitable when sown early i.e., 15th November in the clay loam soils of rice fallows of Central Telangana region of Andhra Pradesh under no till condition.

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Table 1. Performance of maize at different dates of sowing in rice fallow under no till condition

Date of sowing	No. of kernels/cob		Kernel weight/cob (g)		Dry weight at harvest (g/plant)		100-seed weight (g)		Crop duration (days)		Grain yield (kg ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
15th November	486	500	117	127	284	297	24.8	25.0	109	110	5042	5414
30th November	493	495	120	118	291	289	24.8	24.8	110	112	5298	5265
15th December	510	481	134	115	308	278	25.1	24.8	112	111	6101	4965
30th December	399	434	96	104	219	243	24.2	24.4	115	114	3436	4076

Table 2. Performance of sunflower at different dates of sowing in rice fallow under no till condition

Date of sowing	Seed weight/ Plant (g)		Filled seeds/Head		Chaffy seeds/Head		100-seed weight (g)		Crop duration (days)		Seed yield (kg ha^{-1})	
	2007 -08	2008-09	2007-08	2008 -09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
15th November	35.3	29.9	896	828	78	106	4.65	4.53	94	95	1895	1515
30th November	30.6	28.0	832	809	103	116	4.57	4.54	95	95	1567	1349
15th December	22.4	23.6	764	781	141	138	4.43	4.49	95	96	1090	1176
30th December	13.9	21.3	681	756	159	146	4.20	4.31	96	96	636	1000

Table 3. Effect of date of sowing and crop on maize equivalent yield (MEY) (kg ha^{-1}) and net return (Rs ha^{-1}) (mean of two years)

Crops/Sowing dates	15th November	30th November	15th December	30th December	Mean
Maize equivalent yield (kg ha^{-1})					
Maize	5228	5282	5534	3756	4950
Sunflower	4603	3935	3057	2205	3450
Mean	4916	4609	4296	2981	
Net return (Rs ha^{-1})					
Maize	22792	24586	30209	11554	22285
Sunflower	25501	19266	10213	1589	14142
Mean	24147	21926	20211	6572	

MEY (kg ha^{-1})			
Source	Crops	Sowing dates	Interaction
SE±	104	148	209
CD at 5 %	224	317	448
Net Return (Rs ha^{-1})			
SE ±	1313	1858	2627
CD at 5 %	2817	3985	5635

Cost of cultivation (Rs ha^{-1}): Maize: 12,500 (2007), 15,000 (2008); Sunflower: 10,500 (2007), 10,000 (2008)
Price (Rs kg^{-1}): Maize: 7.0 (2007), 8.2 (2008); Sunflower: 19.0 (2007), 22.0 (2008)

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ECONOMIC AND BIOPHYSICAL FACTORS INFLUENCING WATER USE IN IRRIGATION OF GRAPE (*Vitis vinifera*) AND POMEGRANATE (*Punica granatum*) ORCHARDS IN SAADAH GOVERNORATE - REPUBLIC OF YEMEN

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ABSTRACT

Economic and biophysical factors influencing water use efficiency in grape and pomegranate orchards in Saadah Governorate were studied during 2006-07. Primary data were obtained from a sample of 250 farms for grape and 200 farms for pomegranate. The results revealed that the number of irrigations, duration of watering, an organic/chemical fertilisation and distance between source of water (wells) and farm significantly influenced the quantum of water use in irrigation for grape and pomegranate orchards. Chemical fertiliser was an exception to grape. The cost of cubic meter of water, organic manures, distance covering by pipes and night irrigation methods had negative influence on quantity of irrigation water used in both the crops.

Water is a vital natural resource paramount to life, economic development and environmental sustainability. It is a critical input to crops and livestock production. Proper utilisation of water is essential to reap the productivity benefits from agriculture. It should be treated as social and economic good for any civilization. During the last three decades, Yemen has fallen into a water crisis state characterized by very rapid mining of the groundwater resources as a result of excessive water use in agriculture. There are many direct and indirect factors responsible for this problem mainly, growing urbanization, industrialization and population. Increase in population 3.02 % per annum expanded the use of water to meet increasing demands. The open canal system used to connect water from the source to field leads to loss of water due to deep percolation, seepage and surface evaporation. Topography which is characterized by unlevelled fields caused uneven distribution of water in the fields resulting in low irrigation efficiency. The current efficiency is around 30-40 per cent only. Excessive use of water in irrigation system lowers the water table in the wells at the rate of 3-6 meters per annum. This in turn reduced water quality and increased soil salinity. Hence, this study was aimed to estimate economic and biophysical factors influencing quantity and extent of water use by grape and pomegranate orchards in Saadah governorate of Yemen.

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MATERIALS AND METHODS

Multi-stage random sampling procedure was followed in the selection of basins, district, ozlah, village and the farmers. In the first stage, two basins were selected randomly on the basis of common area. In the second stage, three districts were selected randomly from each basin; one district was common for both basins. In each district, four ozlah with highest command area were selected randomly. Two villages were randomly chosen from each ozlah according to size of the village within the common area, which gives a total of 12 villages. In fourth stage, a sample of 272 farmers growing grape and 214 farmers growing pomegranate were selected for the study. The data were collected through personal interview using pre-tested schedules. Cobb-Douglas production function was fitted to analyze the factors influencing the quantity of water use in irrigation for grape and pomegranate crops. The model is specified as follows:

$$QW_{ij} = a \sum_{i=1}^{n} X^{bi}{}_{ij}\, e_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The Cobb-Douglas production function is specified in log-linear form and the coefficients were estimated using ordinary least squares method as follows:

$$Ln\,(QW_i) = Ln\,a + bi \sum Ln\,X_{ij} + e_i \quad \ldots\ldots\ldots\ldots (2)$$

Where:

a = Constant term

b_i = Regression coefficient (i= 1, 2, ….n)

Ln = Natural logarithm.

QW_i = Quantity of water use (M^3/ha.) for selected crops.

X_1 = Number of irrigations.

X_2 = Cost of cubic meter of water (Rs.)

X_3 = Number of hours per watering (Hours/ha)

X_4 = Chemical fertiliser (urea) (kg/ha).

X_5 = Organic manure (bag/ha).

X_6 = Total returns (Rs/ha).

X_7 = Distance between source of water and farms (meters).

X_8 = Distance between source and farm covering by pipes (per cent).

X_9 = Education status (Illiterate = 0, Read/write =1, Basic school = 2, Secondary school = 3, High education = 4)

X_{10} = Size of area (ha).

D_1 = Dummy variable (1 = Earth canal maintenance, 0 = other wise).

D_2 = Dummy variable (1 = Night irrigation methods, 0 = other wise).

D_3 = Dummy variable (1 = Land levelling, 0 = other wise).

e_i = Error term.

RESULTS AND DISCUSSION

The statistics of different variables i.e sample mean, minimum and maximum values and standard deviation are presented in Table 1. The average quantity of water use in irrigation per annum for grape and pomegranate respectively were 14901 and 18345 m^3/ha. The number of irrigations and quantity of water applied varied wide. Grape was irrigated at least twice with 4500 m^3 /ha to as many as 40 times with 32000 m^3 / ha water annually. The number of irrigations for pomegranate also ranged from 2 to 48 with 4000 to 34000 m^3 / ha water. The mean number of irrigations was more than two folds in pomegranate. It was irrigated 23 times while grape was irrigated only 9 times. Pomegranate was also supplied with a high mean quantity of 18345 m^3 / ha while grapes only with 14901 m^3 / ha. The cost of water was more (14 Rs/ m^3) for pomegranate due to more number of irrigations and quantity of water applied. The paradox was that grapes required mean of 58.4 h/ha compared to 49 h/ ha by pomegranate. The fertilizer application was biased towards pomegranate. It received a mean of 314 kg /ha fertilizer dose while grapes were fertilized with 131 kg / ha. Yet, grapes fetched almost more returns of Rs 272 thousand/ha compared to Rs 220 thousand/ha from pomegranate. There were no remarkable differences in the other variables studied.

Table 1. Summary statistic of variables for the analysis

Variables	Grape				Pomegranate			
	Mean	Min	Max	Std. dev.	Mean	Min	Max	Std. dev.
Quantity of water (M^3/ha)	14701	4500	32000	4914	17431	4000	34000	5192
Number of irrigations	9	2	40	4.8	23	2	48	9
Cost of water (Rs/M^3)	9.1	1.4	37	5.7	14	3	62	12
Hours per irrigations (ha.)	58.4	22.2	97	18.6	49	20	82	17
Chemical fertilizer (kg/ha)	131	0	617	154	314	0	667	137
Organic manure (bag/ha)	257	0	741	152	251	0	741	159
Total returns (Rs('000/ha)	272	94.7	1304	273	220	96	1210	89
Distance (meter)	223.1	20	1000	157	231	10	958	181
Pipes covering distance	72.9	0	100	30	71	0	100	33
Education status	0.662	0	4	0.662	0.696	0	4	0.703
Earth canal maintenance.	0.353	0	1	0.479	0.364	0	1	0.482
Night irrigation methods	0.526	0	1	0.5	0.603	0	1	0.49
Farme size (ha)	0.278	0.011	2.025	0.271	0.367	0.014	4.05	0.479

The results of Cobb-Douglas type of production function for grape and pomegranate are presented in Table 2. The coefficient of multiple determination (R^2) was 0.706 and 0.773 for grape and pomegranate respectively. It implies that the explanatory variables included in the model explained 70.6 and 77.3 per cent variation in quantity of water use for irrigation for grape and pomegranate respectively. The F-value of the equation was significant at one per cent level of confidence implying that the variations in the quantity of water use for irrigation

depended mainly upon the explanatory variables included in the model. The relative contribution of specified factors affecting quantity of water use for irrigation in terms of area of two crops can be seen from the estimates of regression equation. The results revealed that the intercept is a constant-term expressed in m^3/ha. It is the quantity of water required by the crop on an average at geometric mean levels. The intercept is significant for both the crops. The coefficient of number of irrigations for grape and pomegranate were respectively 0.62 and 0.72 and positively significant at one per cent level. This indicates that the quantity of water use can be increased by using more number of irrigations. This implies that one per cent increase in number of irrigations with other factors remaining constant would increase the quantity of water use by 0.62 and 0.72 per cent. Hence, more number of irrigations can be planned with higher frequency to improve irrigation efficiency.

Table 2. Economic and biophysical factors influencing quantity of water use for grape and pomegranate in the selected area in Saadah governorate.

S. no.	Variables		Grape		Pomegranate	
			Coeff	t	Coeff.	t
	Intercept	A	6.874 **	26.533	6.323**	17.999
1	No. of irrigations per crop	X1	0.620**	21.346	0.724**	22.245
2	Cost of m^3 water (Rs/M^3)	X2	-0.491**	-17.066	-0.380**	-12.258
3	Hours. per irrigation (ha)	X3	0.488**	11.619	0.395**	8.417
4	Chemicals fertilizer (kg/ha)	X4	0.007	1.563	0.018**	2.411
5	Organic manures (bag/ha)	X5	-0.018**	-2.509	-0.023**	-3.037
6	Total returns (Rs/ha)	X6	0.057**	2.544	0.109**	2.720
7	Distance (meters)	X7	0.057**	3.156	0.039**	2.819
8	Distance covering by pipes (%).	X8	-0.020*	-1.802	-0.021**	-2.132
10	Education status	X9	-0.010	-0.554	-0.048**	-2.924
9	Size of area (ha)	X10	-0.010	-0.739	0.012	0.907
11	Earth canal maintenance.	D_1	-0.043	-1.590	0.015	0.534
12	Night irrigation methods	D_2	-0.068**	-2.704	-0.005	-0.212
	R Square	R^2	0.706		0.773	
	Adj. R Square	R^{-2}	0.692		0.760	
	F		51.779**		57.106**	
	Observations		250		200	

The coefficients of cost per cubic meter of water for two crops in the same order were -0.49 and -0.38. This implies that one per cent increase in the cost of water with other factors remaining constant would decrease the quantity of water use by 0.49 and 0.38 per cent for grape and pomegranate. This result was similar with Rosalyn Bell *et al* (2007), Yacov Tsur1 (2004) and Robert *et al* (2003). The reason for the negative coefficient of the cost per cubic meter of water in irrigation was the result of recent policy reforms in the country on prices of inputs, including diesel, equipment and accessories used for irrigation. This emphasises that the productivity of water use depends on cost and calls for reduction in the prices of inputs used for irrigation systems. The coefficient of hours per irrigation for two crops was 0.488 and 0.395 and was significant at one per cent level. It also influences the quantity of water use. This indicates that the quantity of water use can be increased by using more number of hours per. The positive coefficient of the number of hours per watering per hectare was due to many factors out of which, absence of level fields, more distance between source of water fields, electricity distribution, levelling of field in large scale recalls the credit support into this and type of soils etc. are worth mentioning.

The partial regression coefficient of the chemical fertilizers was significant only for pomegranate. The coefficient of organic manures for grape and pomegranate were -0.018 and -0.023 respectively and significant at one per cent level. The reason for the negative sign of the coefficient of the organic manure indicated the importance the organic manure to improve the characteristic of soil compound to retain the water for long time to be available for the plant.

The coefficient of total returns for the grape and pomegranate were 0.057 and 0.109 respectively and they are significant at one per cent level.This result is corroborated with Indira and Mani (2006). The coefficient of the distance between source of water and farms for grape and pomegranate respectively were 0.057 and 0.039, and these were positive and significant at one per cent level. This result was conflicted with the result of Indira and Mani (2006). The reason for the positive sign of the distance between source of water and farms was due to losses of water in transition and seepage through canals and absence of maintenance of canals by majority of the farmers. However, the coefficient of distance between source of water and farms covering by pipes for grape and pomegranate respectively were -0.02 and -0.021 and these were negatively significant. The reason for the negative sign of the distance between source of water and farms was the total coverage of pipes, by some of the farmers and partially by the rest of the farmers for two crops.

The regression coefficient for literacy was negative and highly significant only for pomegranate growing farmers. The reason for the negative sign of the education status was

due to literacy of more than fifty per cent of the farmers. The coefficient of the night irrigation methods for grape and pomegranate were respectively -0.068 and -0.005, and significant at one per cent level in case of grape. The reason for negative sign of night irrigation method was due to less evaporation. Night irrigation methods were important to decrease the water use in irrigation due to less evaporation from the canals because of the fact that 52 per cent of total sample farmers did night irrigation methods.

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CONSTRAINTS IN ADOPTION OF SYSTEM OF RICE (*Oryza sativa.* L*)* INTENSIFICATION IN WARANGAL DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Rice is an important staple food crop for the Asian region and India is centre of origin with a wide variability. In India, out of the total 604 districts, rice is grown in 560 districts, indicating its importance as a food crop. As rice alone consumes 63% of the total irrigated area in this state, necessitated the need for developing the alternative methods of its cultivation to reduce the stress on this dwindling natural resource. SRI (System of Rice Intensification) is a suitable alternative method of cultivating rice which not only reduces water usage and external inputs like fertilizers but also has a better yield potential. In spite of many concerted efforts since 2004, by the State Agricultural University, Department of Agriculture, and NGOs, the spread of SRI with in Andhra Pradesh is relatively slow. Hence, a study was taken up to find out the extent of adoption of recommended practices by farmers under SRI and problems in its adoption in Warangal district. The results of the study revealed that, farmers with high extension participation, high risk orientation and high scientific orientation who had undergone more number of trainings were more inclined to take up this method. There were certain knowledge gaps such as continuing application of heavy doses of fertilizers, the time required for incubating the soaked seed for its germination etc, which needs to be addressed by the extension agencies. The major hurdles for large scale adoption of SRI observed was the high labour requirement for SRI cultivation and also lack of effective implements like conoweeders for weeding purpose in SRI cultivation.

INTRODUCTION

Andhra Pradesh, referred as the 'Rice bowl' of India, occupying 4th position in area, 2nd position in production and 4th position in rice productivity (2.62t/ha) & contributes 41% of country's rice requirement (Agricultural Statistics at a glance, 2007). Rice is a water-guzzler. Farmers use on an average 4-5000 litres of water to produce one kilogram of paddy. Besides being excessive use of water is wasteful, results in lower yields and adverse environmental effects such as soil salinity and water logging. Substantial increase in the yield and productivity of rice during the green revolution era, plateaued in the recent past. While on the other hand, the input costs are continually escalating resulting in decreased net gains on the investments. The main reasons for the poor yields are improper irrigation management and water logging (Centre for Science and Environment, 1992).

In Andhra Pradesh, rice occupies 63.2% of the total irrigated area (Bureau of Economics and Statistics, 2008). The new method of rice cultivation - SRI offers great potential for optimum utilization of dwindling water resources and increased productivity coupled with lesser inputs of seed and fertilizers compared to conventional method. Experience

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with SRI methods suggests that average rice yields can be about double the present world average without requiring a change in cultivar or the use of purchased inputs (Wang *et al.*, 2002). The system of rice intensification is an alternative method of rice cultivation with some fundamental changes, like transplanting of 8-12 days old young seedlings at wider spacing, using more organic manure, maintaining a thin layer of water instead of conventional flooding, reduced use of chemical fertilizers and pesticides and weeding with a mechanical weeder with the complimentary benefit of root aeration. These practices will help the rice plant to grow vigorously and develop a stronger and healthier root system. The use of organic manure and active root system will help the plant to absorb major and micronutrients efficiently and ensure better yields. The adoption of this technique is slow by the farmers of Andhra Pradesh compared to other states like Tamilnadu, Tripura, Chattisghar, and Orissa.

Against this background, a study was conducted in Warangal district

1. to study the profile characteristics of the sampled paddy farmers,
2. to study the extent of adoption of SRI method of cultivation and
3. to find out the constraints faced by the farmers

MATERIALS AND METHODS

Ex-post facto Research Design was used in the present investigation. In Andhra Pradesh, SRI method was initially introduced in three potential rice growing districts *viz.,* East Godavari, West Godavari and Warangal. Out of these three, Warangal district was purposively selected as the water resources were poor than other two districts. Five mandals *viz.,*Bachannapeta, Devaruppala, Atamakur, Parakala, and Parvatagiri were purposively selected where both government and NGOs are collaboratively working to promote SRI. Two villages were randomly selected from each mandal and 10 farmers from each village thus making the total sample size as 100 respondents. Personal interviews were conducted to elicit the responses from the sampled farmers.

One dependent variable i.e., Adoption and fourteen independent variables *viz;* age, education, farming experience, experience in SRI cultivation, socioeconomic status, trainings undergone, cosmopoliteness, information source utilization, extension participation, economic orientation, risk orientation, scientific orientation, market orientation, and achievement motivation were selected for the study. Adoption schedule was prepared for the study and the independent variables were measured using the previously developed scales. The data were analyzed for frequency, percentages, mean, standard deviation, correlation and multiple linear regression.

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RESULTS & DISCUSSION

The data presented in Table-1 revealed that, majority of the respondents belonged to middle age group (53%) having school level of education (64%) with medium farming (44%) as well as medium level of SRI cultivation experience (69%). Majority of the respondents had undergone trainings (40%), had medium levels of economic orientation (89%), risk orientation (86%), socioeconomic status and scientific orientation (80% each), extension participation (76%), information source utilization (71%), cosmopoliteness and market orientation (63% each).

Table.1 Profile characteristics of the sampled Paddy farmers

(n=100)

S No	Variable	Category	Percentage
1	Age	Young up to 35 years	27
		Middle age 36 to 50 years	53
		Old age More than 50 years	20
2	Education	Illiterate	12
		School education	64
		Collegiate education	24
3	Farming experience (Mean-1.98 & SD-0.75)	Low	29
		Medium	44
		High	27
4	Experience in SRI cultivation (Mean-1.61 & SD-0.49)	Low	39
		Medium	61
		High	0
5	Socio economic status (Mean-86.06 & SD-63.47)	Low	10
		Medium	80
		High	10
6	Trainings undergone (Mean-2.43 & SD-1.2)	Low	22
		Medium	38
		High	40
7	Cosmopoliteness (Mean-6.49 & SD-1)	Low	27
		Medium	63
		High	10

8	Information Source Utilization (Mean-37.2 & SD-4.74)	Low	15
		Medium	71
		High	14
9	Extension participation (Mean-10.71 & SD-1.91)	Low	16
		Medium	76
		High	8
10	Economic orientation (Mean-11.3 & SD-1.35)	Low	11
		Medium	89
		High	0
11	Risk orientation (Mean-15.69 & SD-0.83)	Low	10
		Medium	86
		High	4
12	Scientific orientation (Mean-16 & SD-0.9)	Low	18
		Medium	80
		High	2
13	Market orientation (Mean-24.3 & SD-2.68)	Low	20
		Medium	63
		High	17
14	Achievement motivation (Mean-25 & SD-1.97)	Low	22
		Medium	59
		High	19

High Group: Mean + SD; Low group: Mean- SD

The data in table-2 show that, some variation existed in the extent of adoption of the recommended practices under SRI method of cultivation. Some of the recommended practices like, soaking the seeds in water for 24 hours before transplanting, transplanting the seedlings at the field saturation level, using field markers for spacings in the main field and transplanting only one plant / hill were fully adopted by the farmers.

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Table.2 Extent of adoption of recommended practices of SRI method of cultivation

(n=100)

S No.	Recommended practice	Extent of adoption		
		Fully adopted	**Partially adopted**	**Not adopted**
1	Only 2kg seed to be used for nursery	91	9	0
2	Seeds soaked for 24 hours before raising nursery	100	0	0
3	Incubating the seeds	91	3	6
4	Seed treatment with fungicides	94	3	3
5	Raised beds to be prepared for raising nursery	67	23	0
6	Well decomposed manure to be applied to nursery bed	89	11	0
7	Seeds to be broadcast uniformly on the nursery bed	97	0	3
8	Transplanting with 8-12 days old nursery	87	3	10
9	Nursery to be removed along with soil without causing any damage to nursery	97	3	0
10	Transplanting to be done at field saturation condition	100	0	0
11	Markers to be used for marking	100	0	0
12	Drainage Channels to be dug for every 2 meters in the main field	74	16	0
13	Spacing to be adopted is 25X25 cm	75	25	0
14	Only 16 plants to be transplanted / m^2	74	26	0
15	Only one plant to be raised / hill	100	0	0
16	Nutrients to be provided through organic sources	65	35	0
17	No inundation to be done, field should be at saturation level	80	20	0
18	*Weedicides not to be applied for weeding*	*97*	*3*	*0*
19	Cono weeder to be used for weeding field	87	13	0

However, there appears to be some gaps in adopting the other recommended practices *viz.,* broadcasting seeds uniformly on the raised beds in a thin layer, pulling the seedlings along with soil without causing any damage, and not applying any weedicides (97% each) followed by seed treatment (94%), using only 2 kg seed for nursery, soaking and incubation (91% each), applying well decomposed manure to nursery (89%), transplanting 8 to 12 day old nursery and using conoweeder for weeding in the main field (87%), maintaining field at saturation level (80%), adopting a spacing at 25 X 25 cm in the main field (75%), providing drainage channels and maintaining correct plant density of 16 plants / m^2 (74% each), preparing raised beds for growing nursery (67%) and nutrient management only through organic sources (65% only).

From the above results, it can be inferred that, the gaps that existed in the adoption were mainly in the nutrient management of the main field, preparing raised beds for nursery, maintaining correct plant population etc. It was also observed in the field that, farmers expressed difficulty in maintaining the field at the saturation levels (mud condition without water stagnation) throughout the crop growing period. This clearly there were some knowledge gaps with respect to nutrient management in SRI, hence applying higher doses of fertilizers. This needs a focused attention to improve the availability of the manures and educate the farmers how the organic manures coupled with saturated field conditions and turning the weeds in the field with conoweeder will help exploit the rice genome capacity to yield on par with conventional cultivation. The improvement in the availability of manures will in turn be dependent on the livestock availability in the villages.

The adoption of SRI method of paddy cultivation was positively correlated with experience in SRI cultivation, socio economic status, trainings undergone, cosmopoliteness, information seeking behaviour, extension participation, risk orientation, scientific orientation, and market orientation at 1% level of significance (Table 3); Achievement motivation was significantly correlated at 5% level of significance.

Table. 3 Correlation coefficients of profile characteristics with adoption of SRI method of cultivation by the respondents

S no	Variable	Correlation coefficients of Adoption of SRI
1	Age	0.065
2	Education	0.192
3	Farming experience	0.154
4	SRI Experience	0.485 **
5	Trainings undergone	0.198 *
6	Socio economic status	0.424 **
7	Cosmopoliteness	0.378 **
8	Information seeking behaviour	0.272 **
9	Extension participation	0.649 **
10	Economic orientation	-0.087
11	Risk orientation	0.515 **
12	Scientific orientation	0.504 **
13	Market orientation	0.338 **
14	Achievement motivation	0.237 *

The data further revealed that, better participation of extension officials had positive response towards adoption which is reinforced by risk and scientific orientations, experience in SRI method and attending more number of trainings.

CONSTRAINTS IN ADOPTION OF SRI METHOD OF CULTIVATION

The percentage of respondents who expressed different constraints to adopt SRI are presented in table 4. Most of the farmers felt that there are more weeds in SRI compared to conventional method (85%). As expected, majority of the farmers complained non availability of the labour (78%). In line with earlier findings of WWF-ICRISAT (2009), SRI is more labour intensive, not suitable for saline and heavy soils (76% each) as, faced difficulty in running marker while transplanting and running weeder (75%). Seventy per cent of the farmers felt that, main field preparation is difficult as this requires irrigation channels and proper leveling, 50 per cent expressed difficulty in procuring farm yard manure as there was decrease in livestock population in the villages and non availability of sufficient fodder. There are not enough weeders and markers in their vicinity (48%). SRI cultivation requires skill in transplanting and skilled labour are not available in the villages (44%).

Table.4 Constraints expressed by farmers in adoption of SRI method of cultivation

(n=100)

S no	Problems expressed	Percentage
1.	In SRI cultivation, weed problem is very high compared to conventional method of cultivation	85
2.	SRI method requires more labour where the availability of labour in the villages is scarcer	78
3.	SRI method of cultivation requires more labour	76
4.	SRI is not suitable in heavy black and saline soils	76
5.	It is difficult to run the weeder and marker in the field under field saturation conditions	75
6.	Preparing main field with good leveling and drainage channels is difficult in our situations	70
7.	We are facing difficulty in procuring sufficient quantities of Farm yard manure	50
8.	Conoweeders and markers are not available in time for weeding	48
9.	Skilled labour not available for pulling the nursery and transplanting in the main field	44
10.	Preparing raised nursery bed is difficult	35

CONCLUSION

The results showed that, frequent interactions of the farmers with extension functionaries lead to the formation of a favourable opinion on SRI cultivation and its adoption. Being a new method, wide gaps in the knowledge about SRI were noticed among the respondents especially about application of fertilizers. SRI cultivation being a labour intensive method, majority of the respondents faced labour problem and in running conoweeder for weeding. More focus needs to be given to reduce the knowledge gaps and for developing user friendly implements for weeding. Continuous inundation of rice fields with water and using heavy doses of fertilizers, leads to problems of nutrient losses by leaching, pollution of

ground water and methane emissions from the rice fields that are partially responsible climate change situations. Hence, there is an immediate need to promote SRI method cultivation, focusing more on imparting the principles of SRI during the training programmes and demonstrations, skill development among rural youth and farmers.

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MICROENCAPSULATION TECHNOLOGY: A REVIEW

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ABSTRACT

The development of new functional foods requires technologies for incorporating health promoting ingredients into food without reducing their bioavailability or functionality. In many cases, microencapsulation can provide the necessary protection for these compounds. Microcapsules offer food processors a means to protect sensitive food components, ensure protection against nutritional loss, utilize sensitive ingredients, incorporate unusual or time-release mechanisms into the formulation, mask or preserve flavors/aromas and transform liquids into easy to handle solid ingredients. Various techniques cab be employed to form microcapsules, including spray drying, spray chilling or spray cooling, extrusion coating, fluidized-bed coating, liposomal entrapment, lyophilization, coacervation, centrifugal suspension separation, cocrystallization and inclusion complexation. This article describes the recent and advanced techniques of microencapsulation. Controlled release of food ingredients at the right place and the right time is a key functionality that can be provided by microencapsulation. Timely and targeted release improves the effectiveness of food additives, broadens the application range of food ingredients, and ensures optimal dosage, thereby improving the cost effectiveness for the food manufacturer.

Currently, there is a trend towards a healthier way of living, which includes a growing awareness by consumers of what they eat and what benefits certain ingredients have in maintaining good health. Preventing illness through diet is a unique opportunity to use innovative functional foods (Hilliam, 1996 and Sheehy and Morrissey, 1998). Microencapsulated products often present new challenges to food product developers. Existing ingredients that are incorporated into food systems slowly degrade and lose their activity, or become hazardous, by propagating a chain of oxidation reactions. Ingredients also react with components present in the food system, which may limit bioavailability, or change the colour and taste of the product. In many cases, microencapsulation can be used to overcome these challenges. Microencapsulation is a technology that may be useful for generating small particles that aggregate into thin layers. The simplest of the microcapsules consist of a core surrounded by a wall or barrier of uniform or non-uniform thickness. The thickness of the coat ranges from several to hundreds of micrometres (0.2–500.0 mm) and protects against degradative chemical processes (Rodrigues and Grosso, 2008).

Microencapsulation is defined as a process in which tiny particles or droplets are surrounded by a coating or embedded in a homogeneous or heterogeneous matrix, to give

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small capsules with many useful properties. Microencapsulation can provide a physical barrier between the core compound and the other components of the product. It is a technique by which liquid droplets, solid particles or gas compounds are entrapped into thin films of a food grade microencapsulating agent. The core may be composed of just one or several ingredients and the wall may be single or double-layered. The retention of these cores is governed by their chemical functionality, solubility, polarity and volatility. Shahidi and Han (1993) proposed six reasons for applying microencapsulation in food industry: to reduce the core reactivity with environmental factors; to decrease the transfer rate of the core material to the outside environment; to promote easier handling; to control the release of the core material; to mask the core taste and finally to dilute the core material when it is required to be used in very minute amounts. In its simplest form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase or wall, whereas the wall is sometimes called shell, coating, wall material or membrane. Practically, the core may be a crystalline material, a jagged adsorbent particle, an emulsion, a suspension of solids or a suspension of smaller microcapsules.

Microencapsulation has many applications in food industry such as to protect, isolate or control the release of a given substance which is of growing interest in many sectors of food product development. Converting a liquid into a powder allows many alternative uses of ingredients. One of the largest food applications is the encapsulation of flavours (Shahidi and Han, 1993).

The objective of this paper is to review the state of the art techniques of microencapsulation of food ingredients by different processes and present necessary theoretical and practical information on these processes. The influence of processing technology and matrix materials used on the stability and bioavailability of these ingredients is also discussed.

Structures of microcapsules

Most microcapsules are small spheres with diameters ranging between a few micrometers and a few millimeters. However, many of these microcapsules bear little resemblance to these simple spheres. In fact, both the size and shape of formed micro particles depend on the materials and methods used to prepare them. The different types of microcapsules and microspheres are produced from a wide range of wall materials like monomers and/or polymers (King, 1995; Shahidi and Han, 1993). Depending on the physico-chemical properties of the core, the wall composition and the microencapsulation technique used, different types of particles can be obtained (Fig. 1): A simple sphere surrounded by a coating of uniform thickness; A particle containing an irregular shape core; Several core particles embedded in a continuous matrix of wall material; Several distinct cores within the same capsule and multi walled microcapsules.

Microencapsulation Techniques

Encapsulation of food ingredients into coating materials can be achieved by several methods. The selection of the microencapsulation process is governed by the physical and chemical properties of core and coating materials and the intended application of food ingredients. The microencapsulation processes that are used to encapsulate food ingredients are given in Table 1, which outlines various methods used for the preparation of microencapsulated food systems. Sophisticated shell materials and technologies have been developed and an extremely wide variety of functionalities can now be achieved through microencapsulation. Any kind of trigger can be used to prompt the release of the encapsulated ingredient, such as pH change (enteric and anti-enteric coating), mechanical stress, temperature, enzymatic activity, time, osmotic force, etc. However, cost considerations in the food industry are much more stringent than in the pharmaceutical or cosmetic industries.

In general, three precautions need to be considered for developing microcapsules: formation of the wall around the material, ensuring that leakage does not occur and ensuring that undesired materials are kept out. Encapsulation techniques include spray drying, spray chilling or spray cooling, extrusion coating, fluidized-bed coating, liposomal entrapment, lyophilization, coacervation, centrifugal suspension separation, cocrystallization and inclusion complexation (Table.1) (Gibbs *et al*.1999).

The selection of microencapsulation method and coating materials are interdependent. Based on the coating material or method applied, the appropriate method or coating material is selected. Coating materials, which are basically film-forming materials, can be selected from a wide variety of natural or synthetic polymers, depending on the material to be coated and characteristics desired in the final microcapsules. The composition of the coating material is the main determinant of the functional properties of the microcapsule and of how it may be used to improve the performance of a particular ingredient. An ideal coating material should exhibit the following characteristics (Goud and Park, 2005):

1. Good rheological properties at high concentration and easy workability during encapsulation.
2. The ability to disperse or emulsify the active material and stabilize the emulsion produced.
3. Non-reactivity with the material to be encapsulated both during processing and on prolonged storage.
4. The ability to seal and hold the active material within its structure during processing or storage.
5. The ability to completely release the solvent or other materials used during the process of encapsulation under drying or other desolventization conditions.

6. The ability to provide maximum protection to the active material against environmental conditions (e.g., oxygen, heat, light, humidity).
7. Solubility in solvents acceptable in the food industry (e.g., water, ethanol).
8. Chemical nonreactivity with the active core materials.
9. Inexpensive, food-grade status.

Table 1. Various microencapsulation techniques and the processes involved in each technique

No	Microencapsulation technique	Major steps in encapsulation
1	Spray-drying	a. Preparation of the dispersion b. Homogenization of the dispersion c. Atomization of the infeed dispersiond. Dehydration of the atomized particles
2	Spray-chilling	a. Preparation of the dispersion b. Homogenization of the dispersion c. Atomization of the infeed dispersion
3	Spray-cooling	a. Preparation of the dispersion b. Homogenization of the dispersion c. Atomization of the infeed dispersion
4	A. Extrusion	a. Preparation of molten coating solution b. Dispersion of core into molten polymer c. Cooling or passing of core-coat mixture through dehydrating liquid
	B. Centrifugal extrusion	a. Preparation of core solution b. Preparation of coating material solution c. Co-extrusion of core and coat solution through nozzles
5	Fluidized-bed coating	a. Preparation of coating solution b. Fluidization of core particles. c. Coating of core particles

No	Microencapsulation technique	Major steps in encapsulation
6	Liposomal entrapment	a. Microfluidization b. Ultrasonication c. Reverse-phase evaporation
7	Lyophilization	a. Mixing of core in a coating solution b. Freeze-drying of the mixture
8	Coacervation	a. Formation of a three-immiscible chemical phases b. Deposition of the coatingc. Solidification of the coating
9	Centrifugal suspension separation	a. Mixing of core in a coating material b. Pour the mixture over a rotating disc to obtain encapsulated tiny particles c. Drying
10	Cocrystallization	a. Preparation of supersaturated sucrose solution b. Adding of core into supersaturated solution c. Emission of substantial heat after solution reaches the sucrosecrystallization temperature
11	Inclusion complexation	Preparation of complexes by mixing or grinding or spray-drying

Because no single coating material can meet all of the criteria listed above, in practice either coating materials are employed in combinations or modifiers such as oxygen scavengers, antioxidants, chelating agents and surfactants are added. Some commonly used biocompatible and food-grade coating materials are listed in Table 2. However, chemical modifications of the existing coating materials to manipulate their properties are also being considered. Those modified coating materials exhibit better physical and mechanical properties when compared to individual coating materials.

Category	Coating materials	Widely usedmethods	References
Carbohydrate	Starch,maltodextrins, chitosan, corn syrup solids, dextran, modified starch, cyclodextrins	Spray- and freeze-drying, extrusion, coacervation, inclusion complexation	Godshall (1988); Flink and Karel (1970); Reineccius and Coulter (1989); Reineccius (1989); Reineccius (1991).
Cellulose	Carboxymethyl cellulose,methyl cellulose, ethylcellulose, celluloseacetate-phthalate, celluloseacetate butylate- phthalate	Coacervation, spray-drying,and edible films	Greener and Fennema (1989a); Greener and Fennema (1989b)
Gum	Gum acacia, agar, sodium alginate, carrageenan	Spray-drying, syringemethod (gel beads)	Dziezak, (1991)
Lipids	Wax, paraffin, beeswax, diacylglyerols, oils, fats	Emulsion, liposomes, film formation	Kamper and Fennema, (1984); Kim and Baianu, (1991)
Protein	Gluten, casein, gelatin, albumin, peptides	Emulsion, spray-drying	Ono, (1980)

Ref: Goud and Park, 2005

1. Spray Drying:

Spray drying is the most common microencapsulation technique used in food industry. Spray drying technique for producing encapsulated flavouring was discovered by A Boake Roberts in 1937, when acetone was accidently added to tomato puree which helped him to maintain colour and flavour of tomato powder during spray drying. Subsequently, spray drying has become the most important commercial process for making dry flavourings. Vitamins, minerals, colorants, fat and oil flavour, aroma compounds, oleoresins and enzymes have been encapsulated using this technique. It is an economical, as well as an effective

method for protecting materials and is most widely employed, particularly for flavours for which specialized equipment is not required.

For encapsulation purposes, modified starch, maltodextrin, gum or others are hydrated to be used as the carrier or wall material. The material for encapsulation is homogenized with the carrier material usually at a ratio of 1: 4. The mixture is then fed into a spray dryer and atomized with a nozzle or spinning wheel. Water is evaporated by the hot air contacting the atomized material. The capsules are then collected after they fall to the bottom of the drier (Gibbs, 1999).

Microencapsulation by spray drying offers advantages over conventional microencapsulation techniques by producing microcapsules via a relatively simple, continuous process. The spray drying equipment used is same as is used for the production of dry milk.

Common encapsulating wall materials used in spray drying

The most important step in encapsulation of any core material by spray drying is the selection of suitable wall material, which should form a continuous thin film and should protect the core material from deterioration. The material should be low in cost, should have mild taste and should be stable during storage.The desired functional profile of encapsulating material includes high solubility, effective emulsification, low viscosity at high level of solids, low hygroscopicity, easy release of core material and efficient drying properties. (Lee *et al.,* 2003)

a) Gum arabic (Acacia)

It is one of the oldest and traditional wall materials or carriers used in spray drying. It is a natural exudate from the trunk and branches of leguminous plants of the family Acacia. Although it is one of the most preferred wall materials, alternative carriers are being used for dry flavouring and other core materials due to its low production (300g/plant/year) and high cost.

b) Modified starches:

Chemically modified starches most closely reproduce the functional properties of gum arabic. Natural starches virtually have no emulsifying property. Esterification with cyclic dicarboxylic acid anhydride imparts emulsifying power to partially hydrolysed starches. This technique is practiced on a commercial scale to have the wall material tailor made. The modified starches are found to be superior to gum acacia in emulsifying properties and in retention of volatile flavours during spray drying (Varavinit, 2001).

c) Hydrolyzed starches:

This is one of the most common wall or carrier materials. The hydrolysed starches are available in dextrose equivalent (DE) ranging from 2 to 36.5 and offer good protection against oxidation. These are low in viscosity at high total solid contents. However, they lack in emulsifying properties. It is therefore used along with gum acacia or other emulsifying agents like protein, whey protein concentrates and whey protein isolates. Maltodextrin and low dextrose equivalent (DE) corn syrup solids (CSS) when dried, show matrix forming properties important in the wall system. (Kenyon & Anderson, 1998). When Maltodextrins or CSS are used as wall constituents, it is necessary to incorporate other wall material such as gelating agent, sodium caseinate, whey proteins, lecithins etc. for improving emulsifying characteristics. (Lin, *et al*. 1995).

d) Whey proteins:

As starch and related products lack emulsification properties, they are used as wall materials alongwith surface active wall constituents (Lin, *et al* 1995). Whey protein owing to their structure gives functional properties desired for effective microencapsulation of anhydrous milk fat. Whey protein in combination with maltodextrins and corn syrup solids are reported to be the most effective encapsulation material during spray drying (Kenyon and Anderson, 1998).

2. Spray Chilling

In spray chilling, the material to be encapsulated is mixed with the carrier and atomized by cooled or chilled air as opposed to heated air used in spray drying (Risch, 1995). The outer material is usually vegetable oil in the case of spray cooling (45 to 122°C) or a hydrogenated or fractionated vegetable oil in the case of spray chilling (32 to 42°C). Frozen liquids, heat-sensitive materials and those not soluble in the usual solvents can be encapsulated by spray chilling / spray cooling. It is the least expensive encapsulation technology and is routinely used for the encapsulation of a number of organic and inorganic salts like ferrous sulfate, vitamin, mineral or acidulents as well as textural ingredients, enzymes, flavors and other functional ingredients to improve heat stability, delay release in wet environments, and/or convert liquid hydrophilic ingredient into free flowing powders.

3. Spray Cooling

Spray cooling is called as ‘matrix’ encapsulation because the particles are more adequately described as aggregates of active ingredient particles buried in the fat matrix, while ‘true’ encapsulation is usually reserved for processes leading to a core/shell type of microencapsules. A matrix encapsulation process leaves a significant proportion of the active

ingredient lying on the surface of the microcapsules or sticking out of the fat matrix, thus having direct access to the environment. Particles produced by a matrix encapsulation process generally release their entire content within a few minutes after being incorporated in the food. A non negligible proportion of active ingredients can also be found on the surface of a core/shell type of microcapsule, but the bulk of the ingredient is encapsulated and much slower release kinetics are typically obtained. Even though the process does not lead to a perfect encapsulate, the properties obtained by spray cooling/ chilling are sufficient to achieve the desired delayed release of the ingredient in the actual application. However, a strong binding of the ingredient to the fat matrix can prevent the release of the ingredient even if the fat matrix is melted and/or damaged during processing. (Gouin S, 2004).

4. A. Extrusion:

Extrusion microencapsulation has been used almost exclusively for the encapsulation of volatile and unstable flavors in glassy carbohydrate matrices. The main advantage of this process is the very long shelf life imparted to normally oxidation-prone flavor compounds, such as citrus oils, because atmospheric gases diffuse very slowly through the hydrophilic glassy matrix, thus providing an almost impermeable barrier against oxygen. Shelf lives of up to 5 years have been reported for extruded flavor oils, compared to typically 1 year for spray dried flavors and a few months for un encapsulated citrus oils. Carbohydrate matrices in the glassy states have very good barrier properties and extrusion is a convenient process enabling the encapsulation of flavors in such matrices (Zasypkin and Porzio, 2004). This process can be used for encapsulating nutraceuticals. These processes could, theoretically use glassy carbohydrates as shell material, such as fluidize bed coating, but extrusion remains the most suitable process for such shell materials. The basis of the process was developed by Schultz *et al.,* (1956) and later improved by Swisher (1957). A lower temperature process is developed, in which a mass of potato starch, glycerol and water is processed and gelatinized in a twin screw extruder at about 100°C. The mass is then cooled down and the bioactive formulation is injected in the last barrel, where the temperature should approximately be 50°C. The extruded ropes are cut into pieces and dried (Quellet *et al,* 2001).

B. Centrifugal Extrusion

Centrifugal extrusion is another encapsulation technique that has been investigated and used by some manufacturers. A number of food-approved coating systems have been formulated to encapsulate products such as flavorings, seasonings, and vitamins. These wall materials include gelatin, sodium alginate, carrageenan, starches, cellulose derivatives, gum acacia, fats, fatty acids, waxes, and polyethylene glycol. Centrifugal extrusion is a liquid coextrusion process utilizing nozzles consisting of a concentric orifice located on the

outer circumference of a rotating cylinder i.e., the head. The encapsulating cylinder or head consists of a concentric feed tube through which coating and core materials are pumped separately to the many nozzles mounted on the outer surface of the device. While the core material passes through the center tube, coating material flows through the outer tube. The entire device is attached to a rotating shaft such that the head rotates around its vertical axis. As the head rotates, the core and coating materials are co-extruded through the concentric orifices of the nozzles as a fluid rod of the core sheathed in coating material. Centrifugal force impels the rod outward, causing it to break into tiny particles. By the action of surface tension, the coating material envelops the core material, thus accomplishing encapsulation. The microcapsules are collected on a moving bed of fine-grained starch, which cushions their impact and absorbs unwanted coating moisture. Particles produced by this method have a diameter ranging from 150 to 2000 mm (Schlameus, 1995; Goud and Park, 2005).

5. Fluidized Bed Coating

Fluidized bed technology is a very efficient way to apply a uniform layer of shell material onto solid particles. Interestingly, fluidized bed technology is one of the few advanced technologies capable of coating particles with any kind of shell material like polysaccharides, proteins, emulsifiers, fats, complex formulations, enteric coating, powder coatings, yeast cell extract, etc. Therefore, the controlled release possibilities are considerably more versatile with the fluidized bed technology than with any other technologies. Aqueous solutions of hydrocolloids such as gums and proteins, ethanolic solutions of synthetic polymers and melted fats/waxes have all been used as coating formulations in fluidized bed microencapsulation processes. Spray dried microcapsules can also be further coated by fluidized bed, with a fat layer in order to impart better protection and shelf life. The use of melted fats, waxes or emulsifiers as shell materials is a relatively new but very promising and interesting concept.

In this technique solid particles are suspended in a temperature and humidity-controlled chamber of high velocity air where the coating material is atomized (De Zarn, 1995). Optimal results are obtained with particle sizes between 50 and 500 microns. Particle size distribution should also be narrow. The amount of material that coats the particles is dependent on the length of time that the particles are in the chamber. This technique is applicable for hot-melt coatings such as hydrogenated vegetable oil, stearines, fatty acids, emulsifiers and waxes or solvent-based coatings such as starches, gums, maltodextrin (Tsutsumi, *et al* 1998; Matsuda, *et al* 2001; Gouin 2004).

6. Liposomal Entrapment

A liposome or lipid vesicle is defined as a structure composed of lipid bilayers that enclose a number aqueous or liquid compartments. They have been used for delivery of vaccines, hormones, enzymes and vitamins into the body. They consist of one or more layers of lipids and are nontoxic and acceptable for foods. Permeability, stability, surface activity and affinity can be varied through size and lipid composition variations. They can range from 25 nm to several microns in diameter, are easy to make, and can be stored by freeze-drying. Phospholipids make up the outer layer or layers of liposomes (Figure 3.A). The hydrophilic portion of the lipids is oriented towards the aqueous phase and the hydrophobic groups associate with the hydrophobic ones of other lipid molecules. Folding of the lipid sheet into a spherical shape forms a very stable capsule due to there being no interaction of the lipids with water (Figure 3.B). Aqueous or lipid-soluble materials, but not both, are entrapped in these membranes. Liposomes can range from a few nanometers to microns.

Food applications of liposomes in cheese making is well known (Kirby, 1991). The most common phospholipid in lectin, namely phosphatidyl choline, is insoluble in water and is isolated from soy or egg yolk. The composition of the phospholipids and the process used determine if a single or multiple layers are formed. Fatty acids also make up liposomes and their degree of saturation is dependent on the source. Animal sources provide more saturated fatty acids. They influence the transition temperature which is the conversion from a gel to the more leaky liquid form. Although sugars and large polar molecules cannot permeate through a liposome bi layer, small lipophilic molecules can. (Kim and Baianu *et al* 1991).

7. Lyophilization

Lyophilization, or freeze-drying, is a process used for the dehydration of almost all heat-sensitive materials and aromas. It has been used to encapsulate water-soluble essences and natural aromas as well as drugs. Except for the long dehydration period required (commonly 20 h), freeze-drying is a simple technique, which is particularly suitable for the encapsulation of aromatic materials. The retention of volatile compounds during the lyophilization is dependent upon the chemical nature of the system (Kopelman *et al* 1977).

8. Coacervation

Coacervation, often called ''phase separation,'' is considered as a true microencapsulation technique, because the core material is completely entrapped by the matrix. This technique involves the precipitation or separation of a colloidal phase from an aqueous phase (Dziezak, 1988; Bakan, 1973). Both, simple and complex methods of coacervation can be used. In simple coacervation, a nonsolvent or a more water-soluble

polymer is used. The polymer competes for the solubility for gelatin protein solution by hydrophobic interaction. In complex coacervation, the capsule is formed by the ionic interaction of two oppositely charged polymers, commonly the positive charges on protein molecules and anionic macromolecules such as gelatin and gum arabic (Versic, 1988; Soper, 1995; Brazel, 1999). The complex coacervate is produced when the two opposite charges are neutralized with each other (Soper, 1995).

Coacervation involves the separation of a liquid phase of coating material from a polymeric solution followed by the coating of that phase as a uniform layer around suspended core particles. The coating is then solidified. In general, the batch-type coacervation processes consists of three steps and are carried out under continuous agitation (Pagington, 1986; Kirby, 1991).

1. Formation of a three-immiscible chemical phase

2. Deposition of the coating

3. Solidification of the coating

A large numbers of coating materials have been evaluated for coacervation microencapsulation but the most studied and well understood coating system is gelatin/gum acacia system. However, other coating systems such as gliadin, heparin/gelatin, carrageenan, chitosan, soy protein, polyvinyl alcohol, gelatin/carboxymethylcellulose, B-lactoglobulin/gum acacia, and guar gum/dextran are also suitable for coacervation microencapsulation (Gouin, 2004). In recent years, modified coacervation processes have also been developed that can overcome some of the problems encountered during a typical gelatin/gum acacia complex coacervation process, especially when dealing with encapsulation of heat-sensitive food ingredients such as volatile flavor oils. (Arneodo, 1996; Ijichi *et al*, 1997; Soper and Thomas, 1997).

9. Centrifugal Suspension Separation

Centrifugal suspension is a more recent microencapsulation process. The process in principle involves mixing the core and wall materials and then adding them to a rotating disk. The core materials leave the disk with a coating of residual liquid. The microcapsules are then dried or chilled after removal from the disk. The whole process can take between a few seconds to minutes. Solids, liquids, or suspensions of 30 mm to 2mm can be encapsulated in this manner. Coatings can be 1–200 mm in thickness and include fats, polyethylene glycol (PEG), diglycerides, and other meltable substances. Since this is a continuous, high-speed method that can coat particles, it is highly suitable for foods. One application is to protect foods that are sensitive to or readily absorb moisture, such as aspartame, vitamins, or methionine (Sparks, 1989).

10. Cocrystallization

Cocrystallization is a new encapsulation process utilizing sucrose as a matrix for the incorporation of core materials. The sucrose syrup is concentrated to the supersaturated state and maintained at a temperature high enough to prevent crystallization. A predetermined amount of core material is then added to the concentrated syrup with vigorous mechanical agitation, thus providing nucleation for the sucrose/ingredient mixture to crystallize. As the syrup reaches the temperature at which transformation and crystallization begin, a substantial amount of heat is emitted. Agitation is continued in order to promote and extend transformation/ crystallization until the agglomerates are discharged from the vessel. The encapsulated products are then dried to the desired moisture if necessary and screened to a uniform size. It is very important to properly control the rates of nucleation and crystallization as well as the thermal balance during the various phases (Rizzuto *et al,* 1984)

11. Inclusion Complexation

Molecular inclusion is another means of achieving encapsulation. Unlike other processes discussed, this technique takes place at a molecular level; â-cyclodextrin is typically used as the encapsulating medium. â-Cyclodextrin is a cyclic derivative of starch made up of seven glucopyranose units. They are prepared from partially hydrolyzed starch (maltodextrin) by an enzymatic process. The external part of the cyclodextrin molecule is hydrophilic, whereas the internal part is hydrophobic. The guest molecules, which are apolar, can be entrapped into the apolar internal cavity through a hydrophobic interaction (Pagington, 1986; Goud and Park, 2005;). This internal cavity of about 0.65nm diameter permits the inclusion of essential oil compounds and can take up one or more flavor volatile molecules (Dziezak, 1998). In this method, the flavor compounds are entrapped inside the hollow center of a â-cyclodextrin molecule.

Conclusion

Many nutrition experts and food research institutes are looking for new ingredients with possible health benefits. Phytochemicals, wood-derived ingredients such as phytosterols, pro and prebiotics, new types of carotenoids, trace minerals and polyphenols are examples of such ingredients. Many of these ingredients will be available in a purified form in the near future. Adding them to food systems will often require technological innovations. The challenges are to select the appropriate microencapsulation technique and encapsulating material. Despite the wide range of encapsulated products that have been developed, manufactured, and successfully marketed in the pharmaceutical and cosmetic industries, microencapsulation has found a comparatively much smaller market in the food industry.

The technology is still far from being fully developed and has yet to become a conventional tool in the food scientist repertoire for several reasons. Microencapsulation will certainly play an important role in this process, although it will always make an ingredient more expensive to use where bioavailability should always be considered carefully. The use of microencapsulated food ingredients for controlled-release applications is a promising alternative to solve the major problem of food ingredient delivery faced by food industries, as well as in solving micronutrient deficiencies, especially in countries like India where they are widely prevalent.

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Research Note
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STUDIES ON INFLUENCE OF AGE OF SEEDLINGS AND SPACING ON SEED YIELD AND QUALITY UNDER SYSTEM OF RICE (*Oryza sativa* L.) INTENSIFICATION

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The gains achieved in rice production have been playing a crucial role in ensuring food and nutritional security in India. Achieving the targeted growth rates in rice production largely depends not only on availability of location specific high yielding cultivars but also on adequate supply of quality seed at right time. Maintenance breeding, particularly involving production of Breeder and Foundation seed is facing a stiff challenge in recent times due to enormous production targets to be realised with shrinking resource base and the concept of cost effectiveness of the operation. Seed production farms which usually practice a very high rate of cropping intensity would be benefited by technologies which envisage judicious use of resources both in time and space. Further, the seed production technology which would augment the efforts of breeder in meeting the standards of genetic purity of varieties would be of immense practical and field value.

The SRI methodology was synthesised 20 years ago for raising rice production with much lesser requirement of external inputs and with an intention to benefit resource limited households (Laulanie, 1993). This method envisages paradigm shift in the way plants, soil, water and nutrients are managed in irrigated rice ecosystem producing observable differences in the phenotypes with existing genomes (Uphoff, 2003). The unique prospects of System of Rice Intensification are put to considerable field verification and evaluation. A perusal of research results on SRI indicates desirable changes in crop phenology like reduction in duration, synchronous tillering with uniform maturity of relatively large number of productive tillers resulting from phyllochron effect. The proof of lesser water requirement *per se* in SRI should augur well for the fast shrinking irrigation water base. Further, practice of planting single seedling per hill also provides the breeder a chance of maintaining high genetic purity by adopting rouging at appropriate times. With this background, a study was taken as a part of All- India Coordinated programme on Seed Production, Certification under Directorate of Seed Research (ICAR) to evaluate the influence of age of seedlings and spacing on seed yield and to ascertain the behaviour of seed quality parameters of the produce obtained from SRI in comparison to normal method of paddy cultivation.

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The field study was carried out during *kharif* – 2007 and subsequently after the harvest seed quality was assessed at Seed Research and Technology Centre, A N G R Agricultural University, Rajendra Nagar, Hyderabad. Pre soaked seed of popular rice variety Swarna was incubated for 48 h is gunny bags. Sprout seeds were broadcast uniformly on specially prepared nursery beds for SRI. Transplanting to main field was carried out with 12, 14, 16 days old seedlings and with 27 days as control in three different spacings viz., 30/30 cm, 25/25 cm and 20/20 cm. Marked ropes were used to carry out planting of tiny seedlings @ one seedling per hill as per designated spacing. The experiment was conducted in split plot design in three replications with age of seedlings as main treatments and spacing as sub treatments. Recommended cultural and plant protection practices were followed. Irrigation water was allowed into the field only when the soil developed hairline cracks to maintain muddy slurry condition, except in control wherein standing water of 2.5 cm was maintained. However, a standing water of 2.5 to 5.0 cm was maintained in the entire experimental area during flowering to maturity period. Manual weeding with cono weeder was carried out in vertical and horizontal field directions so as to uproot and trample the weed biomass in the field itself. Weeding was done at an interval of 15 days till the crop attained primordial initiation stage. Observations on yield attributes viz; days to 50% flowering, number of tillers per hill, ear bearing tillers (EBT) per hill, plant height, filled grains per panicle, spikelet fertility and test weight were recorded on five random plants per replication. Plot yields were used to calculate per hectare yields. Unprocessed seed yield was recorded as raw seed yield/ha. Graded seed yield/ha was obtained after cleaning, processing and drying the seed as per procedure. Seed from each treatment were evaluated for germination percentage (ISTA, 1993), speed of germination (Maguire, 1962), shoot length, root length and vigour index (Abdul baki and Anderson, 1973). The data generated was subjected to statistical analysis as per split plot design to test the significance of main, sub treatments and interaction effects.

The results (Table-1) clearly indicated significant differences for the parameters among main, sub treatments and also for interaction effects. Profound influence of age of seedlings and spacing was observed for grain yield and contributing factors - days to 50% flowering, ear bearing tillers and filled grains per panicle. Days to 50% flowering varied significantly due to age of seedlings. Twelve day old seedlings flowered early by at least 12 days compared to control (119 days). Similarly planting age in combination with 25/25 cm resulted in early flowering at 106 days. However, this parameter did not vary due to change in spacing. Early flowering due to planting of younger seedlings could be attributed to quicker establishment of seedlings and synchronised tillering forcing uniform flowering compared to normal age of seedlings (Krishna *et al*. 2008). Similarly, number of tillers and ear bearing

tillers per plant varied significantly due to age of seedlings. Tiller number was maximum and on par with 14 and 16 days seedlings, while ear bearing tillers were maximum in case of 16 days seedlings (23.34). Further, 16 days old seedlings when planted at 30/30 cm spacing recorded maximum number of ear bearing tillers (25.50). Similarly Krishna *et al*. (2008) also reported that twelve day old seedlings recorded highest number of tillers but the tiller number declined with closer spacing as reported by Reddy (2002).

Among the other yield attributes filled grains per panicle and spikelet fertility were directly contributing to higher seed yield. Higher number of filled grains per panicle in control could be attributed to drastic reduction in the number of ear bearing tillers. The percentage of spikelet fertility was also considerably low compared to that of all SRI treatments. This could be due to prolonged tillering phase and non synchronous maturity between and within the panicles leading to production of chaffy grains in contrast to highest fertility percentage of 91.37 in 16 days seedlings with 30/30 cm spacing. However, 100 grain weight and plant height did not vary much among the treatments, even though the SRI treatments recorded higher test weight compared to control apparently due to better filling of the grains.

Significantly higher seed yield of 102.20 q/ha was recorded with 16 days old seedlings planted at 25/25 cm spacing which was 30.9% higher than control planted with same spacing and was followed by 20/20 cm with the same nursery period. Optimum level of plant population coupled with better yield parameters viz; more number of ear bearing tillers and higher percentage of spikelet fertility could have resulted in better performance. The input use efficiency under SRI could have been more in view of improved aeration in rhizosphere and enhanced microbial activity resulting in plants putting forth huge amount of biomass in the form of tillers which ultimately matured uniformly and earlier compared to the conventional method. These results are in conformity with the findings of Udaykumar (2005). The interaction effect between various components also expressed yield gains in SRI. Root growth, tiller density, panicle density, number of grains per panicle, dry matter production during grain filling period and better uptake of nutrients acted synergistically and contributed to the higher yield. Similar views were shared by Thiyagarajan (2006).

Among the seed quality parameters germination percentage and speed of germination with the interaction effects viz., 12 days seedlings with 25/25 cm, 14 days seedlings with 30/30 cm, 14 days seedlings with 20/20 cm and 16 days seedlings with 30/30 cm which were on par with control (27 days seedlings with 25/25 cm, 27 days seedlings with 30/30 cm) indicated that SRI practice will not interfere with germination capacity of the resultant seed, in comparsion to normal methods. This could be attributed to better source-sink translocation of assimilates facilitated by the healthy rhizospheric atmosphere under just saturated field

conditions resulting in sound and well filled seeds. These results are in agreement with the observations of Nandisha and Mahadevappa (1984) and Udaykumar (2005). Maximum shoot length of 13.17 and 12.43 cm was recorded from seed of 12 and 14 day old seedlings planted at a spacing of 25/25 cm. Highest root penetration to 22.5 cm depth was noticed in 16 days old seedlings planted at 20/20 cm and to 22.3 cm in those planted at 25/25 cm. The 16 day old seedlings with 25/25 cm spacing recorded highest seed yield of 102.2 q/ha indicating relationship between root length and yield potential. This could be further substantiated by higher vigour index (3289) recorded in the treatments.

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Table 1. Influence of age of seedlings and spacing on crop growth, yield components, seed yield and seed quality characteristics under SRI

Treatment	Days to 50% flowering	Tillers / hill	Plant height (cm)	EBT/ hill	Filled grains/ panicle	Spikelet fertility (%)	100 seed weight (g)	Raw seed yield (q/ha)	Graded seed yield (q/ha)	Germi-nation (%)	Speed of germi-nation	Shoot length (cm)	Root Length (cm)	Vigour Index
Age of seedlings (Days)														
27	119.33	14.30	83.1	11.80	160.3	77.9	1.78	70.23	65.26	99(88)*	41.28	10.59	20.04	3054
12	107.33	27.93	80.7	21.50	146.0	85.9	1.85	78.83	77.72	98(84)	38.96	11.43	19.44	3046
14	108.00	31.73	79.4	21.43	139.7	84.4	1.83	77.57	75.68	98(86)	36.49	11.06	17.92	2854
16	112.00	31.50	82.3	23.34	144.7	85.9	1.76	105.07	98.37	98(85)	28.79	10.23	20.76	3050
SE±	0.48	0.29	0.3	0.29	1.8	0.9	0.00	0.32	0.29	0.21	0.56	0.29	0.42	51
CD at 5%	1.17	0.71	0.8	0.71	4.3	2.3	0.01	0.79	0.73	0.51	1.43	0.70	1.03	126
Spacing (cm)														
30/30	112.00	31.40	82.0	21.65	149.8	84.5	1.83	71.85	69.52	99(87)	37.03	10.73	18.34	2885
25/25	112.00	26.63	81.3	19.70	156.0	85.4	1.79	84.68	81.37	98(86)	35.56	11.86	20.18	3160
20/20	111.00	21.08	80.8	17.21	137.3	80.6	1.81	92.25	86.88	98(86)	36.54	9.89	20.10	2958
SE±	0.37	0.41	0.4	0.37	1.5	0.8	0.00	0.24	0.36	0.19	0.37	0.24	0.29	30
CD at 5%	0.79	0.86	0.9	0.78	3.2	1.7	0.01	0.50	0.76	0.42	0.78	0.52	0.62	64
Interaction (Days X Spacing)														
27x30/30	120.00	17.30	83.1	12.40	179.0	76.9	1.78	59.70	54.43	99(84)	38.60	10.83	19.67	3019
27x25/25	121.00	14.80	83.3	12.40	159.0	81.1	1.79	74.30	70.60	100(90)	48.00	10.80	19.43	3023
27x20/20	117.00	10.80	82.8	10.60	143.0	75.6	1.78	76.70	70.73	100(90)	37.23	10.13	21.03	3120
12x30/30	107.00	32.10	80.8	25.50	147.0	84.4	1.83	61.20	59.00	98(82)	39.53	10.47	19.47	2933
12x25/25	106.00	27.90	81.4	21.90	151.0	88.8	1.87	81.20	80.87	100(90)	37.47	13.17	20.83	3400
12x20/20	109.00	23.80	79.8	17.10	140.0	84.8	1.84	94.10	93.30	97(81)	39.87	10.67	18.03	2804
14x30/30	109.00	40.50	81.2	23.20	124.0	85.5	1.91	73.30	71.93	100(90)	39.80	11.40	16.83	2823
14x25/25	108.00	33.60	77.9	22.20	160.0	83.3	1.76	74.20	71.80	96(79)	29.60	12.43	18.17	2928
14x20/20	107.00	21.10	79.2	18.90	135.0	84.3	1.82	85.20	83.30	100(90)	40.07	9.33	18.77	2810
16x30/30	112.00	35.70	83.1	25.50	149.0	91.4	1.78	93.20	92.70	100(90)	30.20	10.23	17.40	2763
16x25/25	113.00	30.20	82.6	22.30	154.0	88.4	1.73	109.00	102.20	98(84)	27.17	11.03	22.30	3289
16x20/20	111.00	28.60	81.3	22.23	131.0	78.0	1.78	113.00	100.20	97(81)	29.00	9.43	22.57	3099
SE±	0.80	0.62	0.6	0.59	3.0	1.6	0.01	0.53	0.59	0.37	0.93	0.49	0.69	81
CD at 5%	1.79	1.35	1.4	1.28	6.7	3.5	0.01	1.19	1.29	0.82	2.12	1.10	1.55	186

*Figures in parentheses are Arc sin transformation values.

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ECONOMIC ANALYSIS OF LESS WATER USE RICE (*Oryza sativa*) PRODUCTION TECHNOLOGIES IN KRISHNA WESTERN DELTA COMMAND AREA OF ANDHRA PRADESH

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The increasing demand of water for various sectors viz. domestic, industrial and agriculture will deplete the per capita availability of water resources from 1400 cu m at present, to an estimated quantity of 1000 cu m by the year 2025. The water requirement, which is 65.10 billion cu m at present, is estimated to go up to 69.84 billion cu. m by 2010 and 112.95 billion cu. m by 2025 (A P Water Vision, 2003).

The Krishna Western Delta, which serves 2,42,000 ha of command area with six main irrigation canals having a total length of 322 km, serving Guntur and Prakasam districts in Andhra Pradesh was purposively selected for the present study. There are about 3.99 lakh land holdings operating 3.26 lakh ha of agricultural land with a per capita land holding size of 0.82 ha in Krishna Western Delta command area.

The introduction of canal irrigation in agriculture in Andhra Pradesh brought tremendous changes in cropping pattern, cropping intensity and potential yield of different crops, resulting in considerable benefits to the farmers. However, the benefits are not uniform, as the tail end farmers get less water. On the other hand, the indiscriminate use of irrigation water in the head end areas leads not only to wasting the valuable natural resource but also results in rapid rise of water table due to poor drainage and finally causes the water logging and salinity.

Rice is the major irrigated crop, accounting for approximately 30 per cent of the total irrigated area (Barker R and associates). In view of this, the present study was taken up with the objective of analyzing the economics and water use efficiency of less water use rice production technologies in Krishna Western Delta command area.

The present study is a part of the research work conducted by the A.P. Water Management Project, at Modukuru village of Tsunduru mandal in Guntur district, during *kharif* 2007. The three identified less water use rice production technologies viz. System of Rice Intensification (SRI), Semi-dry (SD) and Rotational Irrigation (RI) along with Farmers' Practice (FP), cultivated in an area of 0.8 ha, 22 ha, 19.6 ha and 1.2 ha, respectively, under Modukuru Branch No.2 canal command in the study area, were selected for analyzing the

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economics and water use efficiency. BPT 5204, a rice variety of 145-150 days duration was cultivated in the study area.

The important practices adopted for the selected production technologies in rice are given hereunder.

Table1. Package of practices for different water saving rice technologies

S. No.	Activities	SRI	Semi-dry	Rotational Irrigation	Farmers Practice
1.	Nursery type	Raised bed nursery	Direct seeding	Normal practice	Normal practice
2.	Seed rate (kg/acre)	2	15-20	15-20	20
3.	Age of planting	8-12 days	-	25 days	25 days
4.	No. of seeds / seedlings per hill	Single	2-3	2-3	2-3
5.	Spacing	25cm×25cm	Solid rows with 22.5cm apart	20cm×15cm	20cm×15cm
6.	Weed control	Rotary weeder at 10 days after transplanting (DAT) and 2-3 weedings at 10 days interval	Pendimethalin @ 1.0 l/ac within 3 days after sowing (DAS)	Using herbicides at initial stage and one hand weeding at 40 DAT	Chemical methods and Manual weeding
7.	Nutrient application	FYM @ 5t/ha + Recommended Dose of Fertilizer	Recommended Dose of Fertilizer	Recommended Dose of Fertilizer	Recommended Dose of Fertilizer
8.	Water management	Saturated condition of field to be maintained.	Depending upon the availability of irrigation water convert the field in to wet system at 45-50 DAS	Once in 48 hours after the disappearance of 5 cm depth of water	Normal practice

The quantity of water released in to Modukuru Branch No.2 canal is measured by constructing a modified rectangular broad crested weir at the head sluice. Finally, the RBC flume was arranged at field level to measure the irrigation water applied. Water use efficiency is calculated by using CRIWAR model (Rob Kselik, 2005), which is a simulation programme for calculation of water requirements of crops. The crop irrigation water requirements (WR) consists of potential evapotranspiration (ETp) minus the effective precipitation, Pe.

$$\text{Water Use Efficiency (WUE)} = \frac{\text{Grain yield (kg)}}{\text{Total water used (WR) (mm)}}$$

$$\text{Water use efficiency benefit} = \frac{\text{Gross returns (Rs.)}}{\text{Total water used (WR) (mm)}}$$

The item-wise cost of cultivation of rice in different production technologies is depicted in Table 2.

The results revealed that the system of rice intensification technology was most expensive over the semi-dry, rotational irrigation and farmers' practice. The total cost of cultivation was Rs. 58645 ha^{-1} in SRI, followed by Rs. 47140 ha^{-1} in rotational irrigation, Rs. 45681 ha^{-1} in farmers' practice and Rs. 39321 ha^{-1} in semi-dry.

Table 2. Cost of cultivation of rice in different production technologies

S. No.	Particulars	Semi-dry (Rs ha^{-1})	Rotational (Rs ha^{-1})	SRI (Rs ha^{-1})	Farmers' Practice (Rs ha^{-1})
I	**Operational costs**				
1	Material costs				
a)	Seed	706	621	125	899
b)	FYM	1472	3152	2000	2668
c)	Fertilizers	4251	6250	7138	6618
d)	Plant Protection Chemicals	2090	5257	6775	4393
e)	Weedicides	1000	400	2000	410
2.	Human labour	13332	12937	19425	13443
a)	Family labour	1333	1294	2742	1343
b)	Hired labour	11999	11644	16682	12101
3.	Machine labour	1438	3319	5725	2077
4.	Interest on working capital	547	719	972	686
Sub-total: Operational Costs		24836	32655	44160	31196
II	**Fixed costs**				
1.	Taxes and cesses	250	250	250	250
2.	Depreciation	150	150	150	150
3.	Rental value of owned land	13750	13750	13750	13750
4.	Interest on fixed capital	335	335	335	335
Sub-Total: Fixed costs		14485	14485	14485	14485
Total cost of cultivation		39321	47140	58645	45681

ECONOMIC ANALYSIS OF LESS WATER

Among the different items of operational costs, human labour cost was very high in SRI with Rs.19425 ha^{-1} owing to labour intensive operations like weed management and harvesting. The seed cost was significantly less in SRI (Rs125 ha^{-1}) followed by rotational irrigation (Rs 621 ha^{-1}), semi-dry (Rs 706 ha^{-1}) and farmers' practice (Rs 899 ha^{-1}). This is due to the lower seed rate recommendation in SRI over the other technologies. Among the material costs, the expenditure incurred on seed was the least followed by weedicides, FYM, plant protection chemicals and fertilizers in all the technologies.

The yields and returns along with water used and water use efficiency of different production technologies in rice are presented in Table 3. The three less water use rice production technologies recorded higher grain yield over farmers' practice. SRI technology recorded the highest yield of 6.85 t/ha, followed by 6.66 t/ha in semi-dry, 6.20 t/ha in rotational irrigation and 5.50 t/ha in farmers' practice. This might be due to the reason that SRI with its high tillering capacity produced higher number of productive tillers and heavier panicles resulting in higher grain yield over other technologies. Rao *et. al*. (2008) also reported similar results of higher yield with water saving rice production systems over farmers' practice. These yield levels are nearer to the current estimates as was stated that the average rice yield in irrigated ecosystems must increase to a level of 6.5 to 7.1 t/ha by 2020, to meet the demand without increase in prices that would adversely affect the poor (Roland J Buresh *et al*.).

Table 3. Yield, returns and water use efficiency of different rice production technologies

Particulars	Semi-dry	Rotational	SRI	Farmers' Practice
Yield (t ha^{-1})	6.66	6.2	6.85	5.50
Cost of cultivation (Rs ha^{-1})	39321	47140	58645	45681
Gross income (Rs ha^{-1})	82805	77225	85111	68733
Net returns (Rs ha^{-1})	43484	30085	26466	23052
B:C Ratio	1.11	0.64	0.45	0.50
Water used (mm)	830	845	803	918
Water use efficiency (kg ha^{-1}mm)	8.02	7.33	8.53	5.99
Water use efficiency benefit (Rs ha^{-1}mm)	52.39	35.56	42.08	25.11

The economic analysis of different rice production technologies revealed that semi-dry cultivation of rice was most profitable when compared with other technologies. Though the yield and gross income were high in SRI, the net benefit-cost ratio was high in semi-dry, owing to the lower cost of cultivation in semi-dry, when compared to other technologies viz. SRI, rotational irrigation and farmers' practice. The net-benefit cost ratio was more than double with 1.11 in semi-dry over the farmers' practice with 0.50. In spite of higher yield, SRI recorded lower net – benefit cost ratio of 0.45 than the farmers' practice (0.50). This could be attributed to the higher cost of cultivation recorded in SRI.

The quantity of water applied per hectare in black cotton soils was lowest in SRI with 803 mm, followed by semi-dry with 830 mm, rotational irrigation with 845 mm and farmers' practice with 918 mm. The higher crop yield coupled with lower quantity of water used resulted in the highest water use efficiency of 8.53 kg ha^{-1}mm in SRI, followed by 8.02 kg ha^{-1}mm in semi-dry, 7.33 kg ha^{-1}mm in rotational irrigation and 5.99 kg ha^{-1}mm in farmers' practice. However, semi-dry recorded the highest water use efficiency benefit of 52.39 Rs ha^{-1} mm, followed by SRI with 42.08 Rs ha^{-1}mm, rotational irrigation with 35.56 Rs ha^{-1}mm and farmers' practice with 25.11 Rs ha^{-1} mm.

Among the three less water use rice production technologies analyzed, SRI recorded the highest total cost of cultivation of 58645 Rs ha^{-1}. It was reduced to Rs 47140 ha^{-1} in rotational irrigation and Rs 39321 ha^{-1} in semi-dry but the per hectare yield was high in SRI (6.85 t) than in semi-dry (6.66 t) and rotational irrigation (6.2 t), inferring that all the three technologies recorded higher yield over farmers' practice of 5.5 t/ha. The water use efficiency was high in SRI over the other technologies. However, the net returns, B.C. ratio and water use efficiency benefit were high in semi-dry, inferring that semi-dry rice production technology was economically viable over the other less water use rice production technologies analysed in the present study.

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Abstracts of Theses Accepted for the Award of Post-Graduate and Doctorate Degrees in the Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad - 500 030

Agro-Techniques for higher yield and quality of sweet corn *(Zea mays L.)* in the southern Agro-Climatic zone of Andhra Pradesh

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The investigations comprised of two experiments conducted for two consecutive *rabi* seasons of 2004 and 2005 at S. V. Agricultural College, Tirupati (13.5^{0}N latitude and 79.5^{0}E longitude), Andhra Pradesh. Weed flora belonging to fourteen taxonomic families was observed in the experimental field, of which six species were grasses, two species were sedges and fifteen species were board leaved weeds (BL Ws). The predominant weed species noticed were *Panicum repens*, *Digitaria sanguinalis, Cyperus iria*, *Celosia argentea and Cleome viscose*.

The lowest density and dry weight of total weeds as well as category wise (grasses, sedges and BL Ws) and nutrient (N, P and K) uptake by weeds were recorded with the plating pattern of P_2 (60 x 20 cm), which were however, comparable with those under P_1 (75 x 16 cm) and significantly lesser than with P_4 (60 x 25 cm) and P_3 (75 x 20 cm), which were om par with each other. With regard to weed control practices, W_3 (2 HW) and W_4 (pre – emergence) application of atrazine + HW) resulted in significantly lesser density ad dry weight of all categories as well as total weeds and nutrient uptake by weeds, which were comparable with W_2 (2 HW) and W_4 (pre-emergence application of atrazine + HW) resulted in significantly lesser density and dry weight of all categories as well as total weeds and nutrient uptake by weeds, which were comparable with W_2 (2 HW) and W_4 (pre-emergence application of atrazine + post emergence application of paraquat), while W1 (Weedy check) recorded the highest weed control efficiency at all the crop growth stages of observation was noticed with W_3. Growth parameters of sweet corn viz., plant height, leaf area index and dry matter production were the highest with P_2, which were however, comparable with P_1 and significantly superior to P_4 and P_3. The planting pattern of P_4 produced enhanced level of yield attributes *viz.,* highest cod length and girth, number of kernel rows cob^{-1}, kernels rows-1. Kernels cob-1 and green cob weight, which were comparable with those obtained with P3. The lowest values of all the yield attributes were associated with P_1, which were comparable with those under P_2. Regarding to weed control practices, W_3 resulted in the highest stature of yield attributes, which were comparable with W_4 and W_2, while the lowest level of all the yield attributes were associated with the weedy check (W_1). The highest quality of kernels (with highest content of protein, reducing and non-reducing sugars) and green fodder (with highest crude protein and lowest crude fibre content) were obtained

with P_4, which were comparable with P_3 and were distinctly superior to P_2, while P_1 resulted in the lowest quality. Regarding the weed control practices, W_3 produced the highest quality of kernels and green fodder, which were comparable with W_4 and W_2, whereas W_1 resulted in the lowest quality. Gross and net returns as well as benefit – cost ration were the highest with P_2, which were however, on par with P_1 and significantly superior to P_4 and P_3, whereas the latter (P_3) resulted in the lowest economic returns. The weed control practice of W_3 resulted the highest gross and net returns, while the benefits-cost ratio was higher with W4 and was comparable with rest of the weed control practices. Weedy check (W_1) resulted in the lowest economic returns. With regards to tome of nitrogen application, T_4 (1/4th basal + ½ knee high + 1/4th tasselling) resulted in the highest stature of growth parameters and yield attributes characters, green cob and fodder yield, nutrient uptake by sweet corn, which were in parity with T_3 (1/3rd basal + 1/3rd knee high +1/3rd tasselling) and T_2 (1/2 basal + 1/4th knee high + 1/4th tasselling), while T_1 (1/2 basal + 1/2 knee high) resulted in the lowest level of all the above mentioned parameters. The highest gross and net returns were realized with N_4, which were statistically similar with N_3 and were significantly superior to N_2. The benefit-cost ratio was the highest with N_3, which was comparable with N_4. The nutrient level of N_1 resulted in the lowest economic returns. Application of nitrogen with T_4 resulted in the highest economic returns, which were comparable with T_3 and T_2, whereas the lowest returns were realized with T_1.The highest post harvest soil nutrient status (nitrogen, phosphorus and potassium) was resulted with N_4, which was significantly higher than with rest of the nutrient levels tried. The nutrient level on N_1 resulted in the lowest post harvest soil available nitrogen and phosphorus than with other nutrient level on N_1 resulted in the lowest post harvest soil available nitrogen and phosphorus than with other nutrient levels. However, N_1 was comparable with N_2, with regard to post harvest soil available potassium.

In conclusion, the present study has revealed that highest yield and quality of sweet corn in the southern-agro climatic zone of Andhra Pradesh could be realized with a planting pattern of 60 x 20 cm (83, 333 plants ha^{-1}), followed integrated weed management practice of pre-emergence application of atrazine + HW at 30 DAS , along with supply of 150-70-50 kg N, P_2O_5 and K_2O ha-1 and application of nitrogen in three splits (1/4th basal + ½ knee high stage + 1/4th taselling). The above combination of agro-techniques was found the most efficient and economically superior, with sustenance of soil fertility. Ph.D(2007).

Agro techniques for rainfed sunflower on vertisols of southern agro-climatic zone of Andhra Pradesh

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The present investigation consisted of two experiments and each of them was conducted during two consecutive seasons at Agricultural Research Station of Acharya N. G. Ranga Agricultural University, Podalakur, Nellore District, A.P. The genotype MSFH-17 sown during second fortnight of September recorded

the tallest plants at 20 DAS during first year, while in second year, the genotype KBSH – 1 sown during second fortnight of October accounted for maximum plant height which was comparable to MSFH-17 sown during second fortnight of September. At 60 DAS and at harvest the tallest plants were observed with KBSH-1 and MSFH-17 sown during first or second fortnight of October during second year. The genotypes and time of sowing differed in their interaction behavior between the years in case of leaf area index. During first year, the genotype KBSH-1 and MSFH-17 sown during first fortnight of October resulted in maximum leaf area index at 20 and 40 DAS. At 60 DAS the genotype KBSH-1 sown during second fortnight of October resulted in maximum leaf area index while at harvest, MSFH-17 sown during first fortnight of October accounted for significantly higher leaf area index. During second year, there was o significant interaction between genotypes and time of sowing at 40 and 60 DAS. At 20 DAS, the genotypes Modern sown either in first or second fortnight of October and KBSH-1 sown during second fortnight of September accounted for the higher but comparable leaf area indices, while at harvest, MSFH-17 sown during first fortnight of November resulted in higher leaf area index. Drymatter production was higher with KBSH-1 sown during second fortnight of October accounted at 20 and 40 DAS, where as, at later stages of 60 DAS and harvest, the genotypes MSFH-17 sown during the same time produced higher drymatter during first year while during second year, the genotypes KBSH-1 sown during second fortnight of October produced higher drymatter at harvest.

The genotype Morden took significantly less number of days to flowering and maturity whereas KBSH-1 took more number of days to 50 per cent flowering and maturity. The highest seed yield was recorded with the genotype MSFH-17 sown at first or second fortnight of October during first and second years respectively. The highest stalk yield was recorded with the same combination during first year while during second year the genotype KBSH-1 or MSFH-17 sown during second fortnight of October produced comparable stalk yields. Oil content was higher in first fortnight of October during both the years and also the genotype KBSH-1 accounted for the highest oil content. With regard to post-harvest nutrient status, KBSH-1 recorded higher soil available nitrogen and soil available potassium while Morden accounted for higher soil available phosphorus when sown during second fortnight of October. Weed density and weed drymatter, at all stages of crop growth, was less with all crop geometries when coupled with pre-emergence application of pendimethalin + one intercultivation at 25 DAS. The same weed control method recorded higher number of total seeds and filled seeds head-1 and also higher filling percentage and test weight. Highest number of total and filled seeds per head were registered with the crop geometry of 60 x 30 cm along with two intercultivation at 25 and 45 DAS coupled with either 125 or 150 per cent recommended done of nutrients. Irrespective of the crop geometry and weed control methods, increasing the nutrients levels resulted in increased soil available nutrient status (N, P2 O5 and K2O). Crop geometry of 60 x 30 cm with pre-emergence application of pendimethalin + one intercultivation at 25 DAS coupled with 125 percent recommended dose of nutrients resulted in maximum gross return, net return and benefit cost ratio. From the present study, it could be concluded that the highest yield of sunflower was realized with the genotype MSHF-17 sown during first or second fortnight of October with a spacing of 60 x 30 cm (55,555 plants ha-1) along with pre-emergence application of pendimethalin + one intercultivation at 25 DAS and application of 125 per cent recommended dose of nutrients (100 – 62.5 – 37.5 kg N, P2 O5 and K2O ha-1). The above combination was found to be the efficient and economically viable package of agro techniques, which can sustain the soil fertility status also. Ph.D(2007).

Nitrogen management through crop residues, organics and inorganic in rice – based cropping system

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Investigations entitled “Nitrogen management through crop residues, organics and inorganics in rice-based cropping systems” were carried out for two consecutive years (2002 – 2003 and 2003 – 2004) at S. V. Agricultural College Farm (ANGRAU), Tirupati (Southern Agro – Climatic Zone of Andhra Pradesh). The field experiment during *Kharif* season was conducted in randomized block design with five replications consisting of four treatments comprising four preceding crops to rice *viz.,* greengram, clusterbean, filedbean and cowpea. After taking the economic yield crop residues were incorporated *in situ.* Rice crop was raised during *rabi* season in the same undisturbed layout, by sub-dividing each of the *kharif* treatments into four sub-plots to which four nitrogen management practices, viz., no nitrogen, 100 per cent nitrogen through fertilizers, 50 per cent nitrogen each through fertilizers and FYM and 100 per cent nitrogen through FYM were assigned. Results of the trail were analysed in a spilt plot design treating effects of incorporation of crop residues of four preceding crops to rice as main plot treatments and four nitrogen management practices imposed on rice as sub-plots. Groundnut was raised during summer season in the same undisturbed layout without imposing any treatment, to study the cumulative and residual effects of incorporation of crop residues and nitrogen management practices to rice. Results of the trial were analysed in a spilt plot design considering cumulative residual effect of incorporation of crop residues of four *kharif* preceding crops to rice as main plots and residual effect of four nitrogen management practices imposed on rabi rice as sub-plots. The test varieties of greengram, clusterbean, field bean and cowpea were LGG-407, Pusa Navabahar, HA-3 and Co-4, respectively, while the test variety of rice was NLR-33359 and that of groundnut was K-134.

All the above mentioned parameters of rice were the highest with the supply of 100 per cent nitrogen through fertilizer, followed by 50 per cent nitrogen each through fertilizers and FYM, 100 per cent nitrogen through FYM and no nitrogen, with significant disparity between each other and all of them were at their lowest with non supply of nitrogen. However, the soil organic carbon content after the harvest of rice was higher with the supply of 100 per cent nitrogen through FYM, which was significantly higher than with supply of 50 per cent nitrogen each through fertilizers and FYM and both of them were significantly superior to supply of 100 per cent nitrogen through fertilizer and no N application, which were comparable to each other. Available nitrogen and available potassium content of soil after the harvest of rice were significantly higher with the supply of 100 per cent nitrogen through FYM, followed by supply of 50 per cent nitrogen each other through fertilizers and FYM, supply of 100 per cent nitrogen through fertilizers and FYM, supply of 100 per cent nitrogen fertilizer and no N application, with distinct disparity between any two. The available soil phosphorus status did not vary to a statistically traceable extent. Incorporation of crop residues of fieldbean to preceding rice has resulted in the

highest stature of growth parameters viz., plant height, LAI and dry matter production and yield attributes *viz.,* number of pods plant^{-1}, 100-pod weight and 100-kernel weight and the highest pod yield, nutrient (N, P and K) uptake, economic returns of groundnut and post harvest fertility status of soil, which were significantly higher than with the incorporation of other three crop residues, which was followed by the incorporation of crop residues of cowpea, clusterbean and greengram, with significant disparity between each other and all of them were at their lowest with the incorporation of green gram crop residues. The interaction effect of different crop residues incorporated and nitrogen management practices tried on rice exerted significant direct influence on the performance of rice as well as the cumulative and residual effect on the performance of groundnut, with similar trend during both the years of study. The interaction effect on various parameters studied on rice and groundnut followed the unaltered trend of combined effect of the best main plot (crop residue) and subplot (N management practice) to be the highest and the combination of the lowest effect of the main and subplots to be the lowest, with distinct disparity between any two of the sixteen combinations. The performance of rice as well as groundnut with reference to various parameters studied, followed the trend of the best plot treatment resulting in the highest value across the sub plots tried and best sub plot treatment resulting in the highest value cross the main plots tried, without any deviation in any respect, during both the years of study. In conclusion, it could be inferred from the investigation that by raising a reasonably short duration leguminous crop (either a pulse crop to vegetable crop depending up on the farming situation) preceding to rice and incorporation of the crop residues after picking the economic yield and supply of 50 per cent recommended dose of nitrogen each through fertilizers and FYM to rice followed by raising groundnut as residual crop, to utilize the residual fertility was found the best integrated nitrogen management packages for rice-groundnut cropping system, not only in terms of higher productivity and economic returns but also for sustaining the soil fertility status at a fairly high level. Ph.D (2007).

Nutrient management for export oriented groundnut

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The present investigation was conducted during *rabi*, 2005 on sandy clay loam soils of dry land farm of Tirupati campus of Acharya N. G. Ranga Agricultural University (S. V Agril. College, Tirupati), Andhra Pradesh. Application of the highest level of major nutrients (60-80-100 N-P_2O_5-K_2O kg ha^{-1}) resulted in the tallest plants, largest LAI and highest dry matter production of groundnut, at all the crop growth stages of observation, while all of them were found to be at their lowest with the lowest level of major nutrient (30-40-50 N-P_2O_5-K_2O kg ha^{-1}). Interaction effect, whenever it was significant, the combination of highest level of major nutrients along with application of all the four micronutrients (M_3S_6) has resulted in the highest stature of all the above mentioned growth parameters, while they were found the lowest with the combination of the lowest level of major nutrients along with no micronutrient application (M_1S_1). All the yield attributes of groundnut viz.,

number of total filled pods plant^{-1}, 100 pod weight, 100 kernel weight and shelling percentage were found to be the highest with 60-80-100 N-P_2O_5-K_2O kg ha^{-1}(M_3), while all of them were found to be at their lowest with 30-40-50 N-P_2O_5-K_2O kg ha^{-1}(M_1). Application of all the four micronutrients has resulted in the highest stature of all the yield attributes of groundnut, while they were at the lowest with no micronutrient application. Interaction was found only in respect of number of total and filled pods plant^{-1} and 100 kernel weight. The highest level of major nutrient (M_3) resulted in the highest pod as well as the haulm yield, which were comparable with M_2 (45-60-75 N-P_2O_5-K_2O kg ha^{-1}). The lowest pod and haulm yields were produced with M_1 (30-40-50 N-P_2O_5-K_2O kg ha^{-1}) Among the micronutrient management practices, combined application of all the four micronutrients (S_6) resulted on the highest pod and haulm yield, while they were at their lowest with no micronutrient application (S_1). The highest oil content of kernel was registered with the lowest level of major nutrients tried (M_1), which was significantly superior to that with M_2 and M_3 with significant disparity between any two successive levels with the lowest oil content in the kernel being recorded with M_3. Protein content in the kernel was the highest with M_3, which was significantly higher than with M_2 and M_1, with significant disparity between any two successive levels of major nutrients tried and the lowest protein content in the kernel was associated with M_1. The highest uptake of N, P and K was registered with 60-80-100 N-P_2O_5-K_2O kg ha^{-1}, while the uptake of all the three major nutrients was the lowest with 30-40-50 N-P_2O_5-K_2O kg ha^{-1}. Application of all the four micronutrients (S_6) recorded the highest uptake of N, P and K, while it was the lowest with no micronutrient application (S_1). Uptake of micronutrients was significantly affected by micronutrient management practices only. Uptake of all the four micronutrients (S_6), which was comparable with S_2 in case of Zn, with S_3 in case of B, with S4 in case of Fe and with S_5 in case of Cu. The uptake of all the four micronutrients was lowest with no micronutrient application (S_1), which was however, comparable with the remaining micronutrient management practices, except S_6 and S_2. The highest gross and net returns were realized with the 60-80-100 N-P_2O_5-K_2O kg ha^{-1}, which were on par with 45-60-75 N-P_2O_5-K_2O kg ha^{-1}, while they were found to be lowest with 30-40-50 N-P_2O_5-K_2O kg ha^{-1}. Gross and net returns were the highest with (S_6) and lowest with (S_1). Regarding interaction effect, the highest gross and net returns were recorded with 60-80-100 N-P_2O_5-K_2O kg ha^{-1} in combination with application of all the four micronutrients (M_3S_6), while they were the lowest with 30-40-50 N-P_2O_5-K_2O kg ha^{-1} along with no micronutrient application (M_1S_1). Benefit-cost ratio was not significantly influenced by different levels of major nutrients tried. The highest B-C ratio was registered with (S_6), which was comparable with S_2 and S_3, while it was the lowest with S_1, which was comparable with (S_4). Interaction effect of major micronutrients was not significant. In conclusion, the study has revealed that export oriented groundnut could be successfully raised in the present domain of study, with higher productivity and quality as well as remunerative economic returns, with the combination of application of 45-60-75 N-P_2O_5-K_2O kg ha^{-1} along with basal application of Zn, Fe, Cu and B. The above nutrient management package has also maintained the soil fertility status, without any impairment of soil health, thus satisfying the sustainability criterion. M.Sc (2007)

Effect of plant stand and nitrogen levels on yield and quality of sweet sorghum

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Department of Agronomy

The present investigation was conducted on sandy clay loam soils of Tirupati campus of Acharya N. G. Ranga Agricultural University, Andhra Pradesh to study the effect of plant stand and nitrogen levels on yield and quality of sweet sorghum. Plant population of 1.11 lakh ha^{-1} resulted in the tallest plants, while the lowest height was with the plant stand of 1.66 lakh ha^{-1}. Plant population of 1.66 lakh ha^{-1} resulted in the highest dry matter production of sweet sorghum, while the lowest was with the plant stand of 1.11 lakh ha^{-1}, at all the crop growth stages. Among the yield attributes, stalk diameter (girth) and thousand grain weight were maximum with the lowest plant stand of 1.11 lakh ha^{-1}, while the fresh stalk yield and millable green cane yield were maximum with the highest plant stand of 1.66 lakh ha^{-1}. The juice quality parameters viz., brix, pol sucrose, total sugars, reducing and non-reducing sugars and total sugars index were higher with the plant stand of 1.11 lakh ha^{-1}, which were comparable to the plant stand of 1.33 lakh ha^{-1}. The highest gross returns, net returns and benefit-cost ratio were recorded with the plant stand of 1.66 lakh ha^{-1}. In case of nitrogen levels, the highest gross returns and benefits-cost ratio were registered with 140 kg but it was comparable to 120 kg N ha^{-1}, while the return was highest with 140 kg N ha^{-1}. Interaction effect due to plant stands and nitrogen levels was found to be significant in case of juice yield and grain yield only. In case of juice yield any one of the plant stands coupled with 140 kg N ha^{-1} and in case of grain yield, the plant stand of 1.33 lakh ha^{-1} along with 120 kg N ha^{-1} proved to be better. In conclusion, the study revealed that sweet sorghum could be successfully raised in the present domain of study, with higher productivity and quality as well as remunerative economic returns, with the combination of agro-techniques of maintaining the plant stand of 1.33 or 1.33 or 1.66 ha^{-1} (with a planting pattern of 45 x 16.7 or 40 x 15 cm respectively) coupled with a nitrogen dose of 120 kg ha^{-1}. M.Sc (2007).

Effect of plant stand and phosphorus levels on the productivity and quality of cluster bean

Student: B. Sreehari Naik Major Advisor: Dr. D. Srinivasulu Reddy

Department of Agronomy

The present investigation was conducted on sandy loam soils of Tirupati Campus of Acharya N. G. Ranga Agricultural University, Andhra Pradesh to study the effect of plant stand and phosphorus levels on the productivity and quality of clusterbean. The experiment was conducted in a randomized block with factorial

concept, replicated thrice, with two factors *viz.,* four plant stands and 4 phosphorus levels. The plant stands were 2.66 lakh ha^{-1} (S_1), 2.96 lakh ha^{-1} (S_2), 3.33 lakh ha^{-1} (S_3) and 3.55 lakh ha^{-1} (S_4), where phosphorus levels 30 kg ha^{-1} (P_1) , 40 kg ha^{-1}(P_2), 50 kg ha^{-1} (P_3) and 60 kg ha^{-1}(P_4). Plant stand and phosphorus levels as well as their interaction in certain instances have significantly influenced the plant growth characters, yield attributes, yield, economic returns and nutrient uptake of clusterbean as well as the post harvest soil fertility status. Plant population of 3.55 lakh ha^{-1}resulted in the tallest plants, largest leaf area index (LAI) and highest dry matter production of clusterbean, at all the crop growth stages of observation, while all of them were found to be at their lowest wit the plant stand 2.66 lakh ha^{-1}. Population of 2.66 lakh plants ha^{-1} took more number of days to 50 per cent flowering as well as maturity. Among the phosphorus management practices. Supply of 30 kg P_2O_5 ha^{-1}took more number of days to 50 per cent flowering as well as maturity. As regards the interaction, in 50% flowering was not found Population of 2.66 lakh ha^{-1} with 30 kg P_2O_5 ha^{-1} took more number of days to attain maturity. The highest thousand seed weight was recorded with 3.33 lakh ha^{-1} . Among the phosphorus levels 60 kg P_2O_5 ha^{-1}recorded the highest thousand seed weight, as regards the interaction effect plant stand of 3.33 lakh $ha^{-1}$with 60 kg P_2O_5 ha^{-1} noticed highest weight of thousand seed of clusterbean, which was however, on par with each other combinations. Stalk yield of clusterbean was maximum with the population of 3.55 lakh ha^{-1} recorded the highest stalk yield of clusterbean. As regards the interaction effect the plant population of 3.55 lakh ha^{-1} with 60 kg P_2O_5 ha^{-1}recorded the maximum stalk yield of clusterbean. At all the stages of crop growth, the highest nitrogen, phosphorus and potassium uptake by the clusterbean crop was recorded with the plant stand of 3.55 lakh ha^{-1}. Among the different phosphorus and potassium uptake was recorded with application of 60 kg P_2O_5 ha^{-1}, as well as lowest with 30 kg P_2O_5 ha^{-1}. As regards interaction effect the plant population of 3.55 lakh $ha^{-1}$with the plant stand of 2.66 lakh $^{-1}$ with 30 kg P_2O_5 ha^{-1}. The highest gross returns, net returns and benefit cost ratio were noticed with plant stand of 3.33 lakh ha^{-1}. Among the phosphorus levels, the highest economic returns were realized with application of 60 kg P_2O_5 ha^{-1}. As interaction effect the plant population of 3.33 lakh ha^{-1} with 60 kg P_2O_5 ha^{-1} was recorded highest economic returns. 30 kg P_2O_5 ha^{-1} has resulted in poor performance of clusterbean crop, with the lowest stature of growth parameters, yield attributes, yield, nutrient uptake and economic returns of clusterbean as well as post harvest soil fertility status. In conclusion, the study has revealed that population of 3.33 lakh ha^{-1} supplied with 60 kg P_2O_5 ha^{-1} was the best combination of agrotechniques tried, since this combination has resulted in higher yield as well as economic returns, besides maintaining the soil fertility status, thus satisfying the productivity, economic and soil health sustainability criteria. M.Sc (2007)

Economic of production and value addition of economic of coconut in Pondicherry region

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Department of Agricultural Economics

The present investigation was undertaken to examine the cost structure, economic viability and value addition in coconut. Three communes and six villages having maximum area under coconut orchards were listed out and 40 farmers were selected at random. The sample so selected was subjected to post classification into pre-bearing orchards (1st to 6th year) and bearing orchards (7th to 60th year), which comprised of 3 stages *viz.,* yield increasing period (7th to 30th year), yield stabilization period (31st to 50th year) and yield declined period (51st to 60th year). Data were collected from the selected respondents on well structured survey schedule designed for the purpose for the year 2005 – 2006. Conventional analysis and project evaluation techniques were employed to analyse the data. The total labour required to establish and maintain the coconut orchard during the economic life period was 13, 250.04 mandays per hectare of which irrigation, harvesting and watch and ward took major share with 3710 mandays (22.35%) respectively. The commercial cost of cultivation (Cost 'C') for the life span of coconut orchard was Rs. 34, 59, 480.27 per hectare. The gross and net income realize for the entire economic life period were Rs. 74, 52, 075.85 and Rs. 39, 92,595.58 per hectare, respectively. The net present worth was as high as Rs. 2, 44,715.80 at 10.0per cent and Rs.37.137.90 at 20.0 per cent. The IRR was calculated at 29.20 per cent. All the measures indicated the economic viability of coconut cultivation. The value addition in coconut coir industry sounded good. The raw material (husk) which costs Rs. 121.23 per quintal had been converted into the final product (rope) and its sale price was Rs. 628.50 per quintal. M.Sc (2007).

Reaction of different entries of field bean, *(Dolichos lab lab* L.) to insect pest complex and biology of plume moth *Sphenarches caffer*

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Department of Agricultural Economics

Studies on the reaction of different entries of field bean to insect pest complex and effects of morphological parameters, biochemical constituents, anatomical inclusions together with molecular characterization of promising entries of fields bean were carried out during *rabi* 2006-07 in S. V. Agricultural College, Tirupati.

Eighty four cultivars of fields bean were screened under field conditions against plume moth, *Sphenarches caffer, spotted pod borer, Maruca vitrata* and gram pod borer, *Helicoverpa armigera* and pod

bug *Clavigralla gibbosa*. The cumulative incidence (from 50 to 70 DAS) of larvae of plume moth was significantly highest in GL-127 with larvae per plant. Population of *M. vitrata* in MAC-6 was the highest with 42 larvae per plant, while 8 larvae per plant of *Helicoverpa* were noticed in GA-49. The difference in pod damage among 84 genotypes of field bean was ranging and ranged from 18 to 59 per cent. The genotypes AVT-FB (SD)-1-6-4 was sustained highest pod damage (59.12%), while TCR-137 suffered lesser pod damage of 18.75%. Among morphological and biochemical constituents, pod length, protein and reducing sugar content of pods were positively correlated with pod damage, while negative and significant correlation were observed with pod width, rind thickness, toughness of pod, phenols, silica, fibre content of the pod and pod damage due to pod borer. Biology and morphometrics of Plume moth, *S. caffer* were studied under laboratory conditions where 28±2^{0}C temperature and 75±2 per cent relative humidity prevailed. The average incubation period ranged from 1.86-4.1 days, while mean larval period ranged from 12.70-21.54 days. The total life cycle was completed in 29.79-49.85 days on field bean. It was observed that *S.caffer* was parasitized by *Tropimeris monodon* to an extent of 64-82%. RAPD assays of genotypes with varied level of resistance to insect pest of field bean indicated the presence of wide range of variability among entries. The genotypes TCR -137 which possessed desirable attributes of resistance to pod borer can be utilized in the genetic enhancement studies in view of the diverse base variation in DNA profile and phenotypic diverse. M.Sc.(2007).

Studies on the Entomopathogenic fungus *Nomuraea rilleyi(*Farlow) Samson with Special Reference to *Spodoptera litura Fabricius*

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Department of Entomology

The pathogenicity tests of *N. rileyi* against II, III and IV instar larvae of *S. litura* Fabricius reared on three different host crops *viz.,* castor, groundnut and tomato were carried out. *N. rileyi* infected larvae died by exhibiting the characteristic symptoms. Relatively higher mortalities of larvae were recorded, when castor leaves were provided as food after treating with *N. rileyi* spores. With respect to individual instars, as the concentration decreased, the larval susceptibility was also decreased showing the positive correlation.

The larval mortality was in negative association with age of the *S. litura* larvae. The mean larval mortalities of 85.65, 61.66 and 31.11 per cent were obtained with the optimum concentration used i.e. 1 x 10^7 spores ml^{-1}.

The pupal mortalities and the malformed adults were higher with higher concentrations in all the instars where slight prolongation of incubation period was noticed with reduced concentrations.

Among four different temperatures i.e. 20^{0}C, 25^{0}C, 30^{0}C and 35^{0}C tested for sporulation of *N. rileyi*, 25^{0}C performed the highest sporulation.

Among seven insecticides and four fungicides tested, relative safety of spinosad, l-cyhalothrin to *N. rileyi* was proved.

The above experiments were conducted under laboratory conditions in the Department of Entomology, S.V. Agricultural College, Tirupati during 2006-2007. M.Sc.(2007).

ABSTRACTS

Farming Performance of Potato Cultivators of Hassan District in Karnataka

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Department of Extension Education

Ex-post-facto research design was followed for the study. The investigation was carried out in three mandals of Hassan district where potato is intensively grown. 150 farmers were randomly selected from six villages of three mandals. The data were collected by personal interview method through structured interview schedule and analysed by employing suitable statistical methods.

Majority of the potato farmers were middle aged with medium education; social participation, experience in potato cultivation, achievement motivation, innovativeness, self confidence, economic orientation, management orientation, risk orientation, scientific orientation, utilization of available assistance, high deferred gratification and low information seeking.

Correlation analysis revealed that there was a positive and significant relationship between knowledge and independent variables i.e., education, social participation, achievement motivation, innovativeness, self confidence, economic orientation, management orientation, risk orientation, scientific orientation, information seeking and utilization of available assistance. Whereas age, experience in potato cultivation and deferred gratification were not significantly correlated with the knowledge of the respondents about recommended practices.

Correlation analysis revealed that there was a positive and significant relationship between farming performance and independent variables i.e., education, social participation, experience in potato cultivation, achievement motivation, innovativeness, self confidence, economic orientation, management orientation, deferred gratification, scientific orientation and utilization of available assistance. whereas age, risk orientation and information seeking were not significantly correlated with the farming performance.

Regression analysis revealed that all the 14 selected independent variables put together explained about 43.79 per cent variation in knowledge and 55.08 per cent variation in farming performance levels of potato farmers. Further it also revealed that education, social participation, innovativeness and information seeking in knowledge and experience in potato cultivation, management orientation, scientific orientation and utilization of available assistance in farming performance had positively and significantly contributed to most of the variation.

High cost of critical inputs, lack of subsidies, lack of support price, syndicate of buyers and lack of credit facilities were the major problems encountered by the farmers. The respondents expressed regulations to lower the cost of inputs, timely and adequate supply of inputs, provision of credit facilities and storage facilities as the major suggestions to overcome the problems faced by them. M.Sc.(2007).

Entrepreneurial Behaviour of Prawn Growers in Nellore District of Andhra Pradesh

Student: B. Vidhyadhari Major Advisor: Dr. T. Prabhakara Sastry

Department of Extension Education

Ex-post-facto research design was followed in the study. Nellore district in Andhra Pradesh was purposively selected for the study. Our of 46 mandals in Nellore district, three mandals viz; Indukurpet, Thotapalligudur, Muthukur were purposively selected. Two villages were selected from each of the three mandals making a total of six villages viz; Nidumusali, Gangapatnam, from Indukurpet mandal Edur. Papireddypalem, from Thotapalligudur mandal and Pantapalem and Nelatur from Muthukur mandal were selected randomly. One hundred and twenty respondents were selected from the six villages by employing simple random sampling method. The data were collected by personal interview method through structured interview schedule. Appropriate statistical procedures were employed to analyze and interpret the data.

The study revealed that majority of the prawn growers were middle aged, educated up to primary level with medium level of social participation, extension contact, income, scientific orientation, marketing facilities, management orientation, value orientation and credit orientation.

Correlation analysis revealed that the independent variables of the respondents namely Education, social participation, extension contact, income, scientific orientation, management orientation and value orientation had positive and significant relationship whereas age, marketing facilities and credit orientation had non significant relationship with entrepreneurial behaviour of prawn growers. Hence, the above variable should be given due consideration while formulating and implementing programmes for the development of entrepreneurial behaviour of prawn farmers.

Regression analysis revealed that all the selected ten independent variables put together explained about 46.53 per cent variation in entrepreneurial behaviour of prawn growers. Age, education, social participation, management orientation, value orientation and credit orientation have significantly contributed to most of the variation in entrepreneurial behaviour of prawn growers.

Lack of quality seed and feed, lack of market support price, high cost of inputs, lack of power supply, lack of cold storage facilities, inadequate knowledge about diseases, inadequate credit facilities, lack of subsidies were the problems encountered by the prawn growers.

Provision of quality seed and feed, provision of minimum support price, provision of inputs at reasonable rate, supply of power for about 12 to 15 hours per day, establishment of cold storage units, strengthening of training and research to update knowledge, credit through banks with low interest rate, subsides to be provided on critical inputs were the suggestions given by the prawn growers for better entrepreneurship. M.Sc.(Ag.)(2007).

ABSTRACTS

Heterosis in Field Bean (*lablab purpureus* (L.) Sweet)

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Department of Genetics and Plant Breeding

The present investigation was carried out during *Kharif*, 2006 to study the genetic parameters, heterosis, character associations and path coefficient analysis in 17 parents and their 15 F_1 cross combinations of field bean (*Lablab purpureus* L. Sweet). The experiment was laid out at Dryland Farm of Regional Agricultural Research Station, Tirupati in a randomized block design with three replications and observations were recorded on sixteen characters.

Analysis of variance indicated the presence of significant genotypic differences for fifteen characters. The genotypes *viz.,* TFB-5, FB-2, GA-2-1, EC-22096 and GA-32-1-8 showed high mean performance for pod yield and most of its components. Among the crosses, the crosses *viz.,* EC-7467 x TFB-1, GA-2-1 x TFB-5, FB-2 x TFB-5, Madagandanahalli x TFB-5 and GA-16 x TFB-5 recorded high mean performance for pod yield and most of its components.

A perusal of genetic parameters revealed high PCV and GCV for characters days to flowering and phenol content in parents, whereas in F_1 progenies high PCV and GCV values were observed for days to flowering and number of inflorescences per plant. Further, high heritability coupled with high genetic advance as per cent of mean was observed for days to flowering, days to maturity, phenol content, plant height, number of pods per plant, number of inflorescences per plant, SLA 40 DAS, pod yield per plant and SLA 60 DAS in parents as well as F_1's indicating predominance of additive geneaction in the inheritance of these traits. These characters can be further improved by following simple selection.

The highest magnitude of heterosis was observed for days to flowering, number of inflorescences per plant, SLA 40 DAS and days to maturity while moderate for pod yield per plant, carbohydrate content and SLA 60 DAS. Low magnitude of heterosis was recorded for SCMR 40 DAS, SCMR 60 DAS, potein content, vitamin-C content, number of pods per plant, 100-seed weight, phenol content, plant height and number of branches per plant. The best heterotic crosses identified were EC-7467 x TFB-1 for pod yield per plant, GA-2-1 x TFB-5 for number of pods per plant, MAC-8 x TFB -5 for number of inflorescences per plant and SCMR 40 DAS, EC-83-A x TFB-1 for SLA 40 DAS, Krishnapur-II x TFB-5 for protein content and number of branches per plant, GP-18-7 x TFB-1 for phenol content and number of branches per plant, GP-18-7 x TFB-1 for number of branches per plant and carbohydrate content, PLS-22016 x TFB-1 for phenol content and CO-1 x TFB-5 for plant height were the best heterotic crosses for their respective characters. The significantly high heterobeltiosis and standard heterosis observed for pod yield and its components in these crosses might be utilized for its exploitation by heterosis breeding methods.

Character association studies indicated the significant positive correlation of number of pods per plant, number of inflorescences per plant, SCMR 60 DAS and days to flowering with pod yield and also among themselves. Path coefficient analysis revealed that number of pods per plant, SCMR 60 DAS and number of inflorescences per plant were the important attributes in formulating selection criteria for effective improvement of pod yield in field bean. M.Sc.(2007).

Genetic Divergence Studies in Finger Millet (*Eleusine coracana* (L)Gaertn.)

Student: Jaya Lakshmi C. Major Advisor: Dr. K. Hari Prasad Reddy

Department of Genetics and Plant Breeding

The present investigation was carried out to study the genetic divergence, genetic parameters, character association and path coefficient analysis in thirty finger millet genotypes for twelve quantitative characters. The experiment was carried out in randomized block design, with three replications at the wet land farm, S.V. Agricultural College, Tirupati during *Rabi,* 2006. The data was recorded on twelve quantitative characters.

Analysis of variance indicated the existence of significant genotypic differences for all the twelve quantitative traits. The genotypes viz., GEC 82, GEC 381, PR 202, PPR 2698, Godavari and Saptagiri showed high mean performance for grain yield as well as for most of the yield components.

The analysis of genetic parameters revealed higher genotypic and phenotypic coefficients of variation, heritability and genetic advance as per cent of mean for number of fingers per ear, total dry matter production, main ear length, total tillers per plant, plant height and grain yield per plant indicating that simple selection could be practiced for improving these characters.

The multivariate analysis revealed that the thirty genotypes had considerable amount of diversity. The Mahalanobis D^2 analysis formed ten clusters. The mode of distribution of genotypes of various clusters was at random suggesting that the geographic diversity might not be an index of genetic diversity. Super imposition of genotype was observed in metroglyph analysis because of close proximity of two variables taken for plotting the genotypes. The characters viz., total tillers per plant, test weight, number of fingers per ear and main ear length contributed maximum towards genetic divergence in both D^2 analysis and canonical root analysis. Further, canonical root analysis confirmed the clustering pattern obtained by D^2 analysis. Based on Tocher's Method of clustering the genotypes viz., GEC 93, GEC 297, GEC 268, PPR 2698, GEC 208 and Godavari were suggested for inclusion in hybridization programmes for obtaining desirable and novel recombinants.

Character association studies indicated the significant positive correlation of days to 50 per cent flowering, days to maturity, plant height, main ear length, test weight, total dry matter production, harvest index and total tillers per plant with grain yield per plant and among themselves. Path coefficient analysis revealed that high positive direct influence of harvest index, total dry mater production and days to 50 per cent flowering on grain yield per plant. The characters main ear length and SLA had indirect effect on grain yield per plant via harvest index. Therefore, simultaneous selection for these traits is suggested for improvement of grain yield per plant in finger millet. M.Sc.(2007).

Morphological and RAPD Based Gene Diversity Studies among Released Cultivars and Pre-Release cultures of Groundnut (*Arachis hypogaea* L.)"

Student: N. Suneetha Major Advisor: Dr. R.P. Vasanthi

Department of Genetics and Plant Breeding

The present investigation was carried out during *Kharif,* 2006 to study the genetic divergence(D^2 Statistic and RAPD markers), variability, character association and path co-efficient analysis in 29 released and pre-release cultures of groundnut. The experiment was laid out at Regional Agricultural Research Station, Tirupati in a randomized block design with three replications. Data were recorded on 16 morphological, yield and yield attributes and 10 physiological characters.

Analysis of variance indicated the existence of significant genotypic differences for all the characters except for number of primary branches number of mature pods per plant and number of immature pods per plant. The cultivars *viz.,* Tirupati-4, TG-39, Abhaya, R-2001-2, JL-24, TCG-750 and K-4 showed high mean performance for pod yield as well as for most of yield components.

Analysis of genetic parameters revealed that GCV, PCV heritability (broad sense) and genetic advance as per cent of mean were relatively high for length of primary branches, length of main axis, days to emergence, weight of immature pods per plant, number of fully expanced leaves, 100-seed weight, harvest index, pod yield per plant, leaf area duration (LAD), crop growth rate (CGR), leaf area index(LAI), net assimilation rate (NAR), specific leaf area (SLA) at 72 DAS and seedling vigour index indicating the involvement of additive gene action. Therefore, simple phenotypic selection could be efficient to improve these characters. The remaining characters, number of primary branches per plant, days to 50 per cent flowering, leaf length, leaflet length, leaflet width, number of mature pods per plant, number of immature pods per plant, SCMR and germination percentage had moderate to low GCV, PCV heritability and genetic advance as per cent of mean indicating the influence of non-additive gene action. Hence, selection in advanced generations would be effective for improvement of these characters.

Genetic divergence studies by Mahalanobis's D^2 analysis revealed considerable variability among 29 released and pre-release cultures of groundnut and were grouped into 9 and 8 clusters based on morphological, yield and yield attributes and physiological characters respectively. The characters, harvest index, days to emergence, length of main axis, leaf area index, crop growth rate and net assimilation rate contributed maximum towards genetic divergence and this was confirmed by canonical analysis. The cultivars, TCGS-888, TCGS-913, R-2001-2, Tirupati-4, Narayani, JL-24, TCGS-645, TCGS-717 could be selected as effective parents to improve the respective morphological and physiological characters.

RAPD marker studies detected a high level of genetic variation among the 12 groundnut cultivars selected. A high degree of polymorphism was obtained with the primers OPJ-6 (11 bands), OPA-3 and OPH-7(10 bands). The similarity index values ranged from 32.60% to 92.9% indicating a wide range of genetic diversity.

Character association studies revealed significant positive correlation of number of primary branches per plant, number of mature pods per plant, 100-seed weight, LAD, LAI, CGR, SLA and harvest index with pod yield per plant and among themselves. Path co-efficient analysis indicated that number of mature pods per plant, number of primary branches per plant, 100-seed weight, LAD, CGR, LAI at 36, 72 DAS, germination percentage and SLA at 72 DAS were important attributes directly influencing the pod yield in groundnut. M.Sc.(2007).

Genetic Divergence and Character Association Studies in Rice (*Oryza sativa L.)*

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Department of Genetics and Plant Breeding

The present investigation was carried out during *Kharif,* 2006^07 to study the genetic divergence, genetic parameters, character associations and path co-efficient analysis in forty eight rice genotypes. In addition RAPD analysis was carried out for 20 genotypes of rice (*Oryza sativa* L.). The experiment was laid out at wetland farm of Sri Venkateswara Agricultural College, Tirupati in a randomized block design, with three replications. Data were recorded on fourteen quantitative and qualitative characters.

Analysis of variance indicated the existence of significant genotypic differences for all the fourteen attributes. The genotypes *viz.,* Bhadraj, Triguna, Dular, IR-64, BPT-1235 and ADT-43 showed high mean performance for grain yield as well as for most of yield and quality components.

Genetic divergence studies by Mahalanobis's D^2 analysis indicated the existence of significant diversity of forty eight rice genotypes and were grouped into fifteen clusters. The results revealed that the geographic diversity might not always be related to genetic diversity. The characters plant height and panicle

length contributed maximum towards genetic divergence in both D^2 analysis and canonical root analysis. The inter-cluster distance was maximum between cluster XIV and XV (1855.88). The genotype Velluthachera (Cluster XIV) and Heera (Cluster XV) have maximum number of grains per panicle, grain yield per plant and kernel length after cooking. The cross between the genotypes Velluthachera x Heera is found to be diverse and utilized for the exploitation of transgressive segregants.

Character association studies revealed that the traits *viz*., number of grains per panicle, days to 50 per cent flowering, days to maturity, number of effective tillers per plant, harvest index, panicle length and 1000-grain weight had significant positive correlation with grain yield. Path co-efficient analysis revealed that number of grains per panicle, number of effective tillers per plant, days to 50 per cent flowering, plant height, kernel width and 1000-grain weight were the important attributes in formulating selection criterion for effective improvement of grain yield and quality.

RAPD analysis detected a high level of genetic variation among the 20 rice genotypes. a high degree of polymorphism was obtained with the primers OPH 19 (8 bands), OPH 4 (5 bands) and OPB 8 (5 bands). The similarity index values were ranged from 0.545 to 0.968 indicating a wide range of genetic diversity. M.Sc.(2007).

Genetic Analysis for Yield and Leaf Spot Resistance in Groundnut (*Arachis hypogaea* L.)

Student: Tsewang Dolma Major Advisor: Dr. M. Reddi Sekhar

Department of Genetics and Plant Breeding

The present investigation consisting of 33 genotypes of Groundnut (*Arachis hypogaea* L.) was undertaken to study the variability and genetic parameters, genetic divergence, character association, path analysis, disease screening for late leaf spot resistance at the field as well as the molecular diversity analysis was carried out in ten selected genotypes drawn from various clusters based on D^2 analysis. The experiment was laid out at Wetland farm, S.V. Agricultural College, Tirupati in a Randomized Block Design with three replications during late *kharif,* 2006. The data were recorded on ten quantitative characters as well as for disease screening for late leaf spot resistance.

Analysis of variance indicated the existence of significant genotypic differences among genotypes for all the characters studied. The genotypes ISK-04-03 and Narayani showed high mean performance for kernel yield and its component characters *viz.,* days to maturity, number of primary branches per plant, shelling percentage, pod yield per plant, harvest index, sound mature kernel per cent and plant height.

Genetic parameters revealed high GCV and PCV, high heritability coupled with high genetic advance as percent of mean for sound mature kernel per cent, test weight, kernel yield per plant and harvest index indicating that these traits can be improved by simple selection methods.

The Mahalanobis's D^2 analysis formed six clusters. Cluster I comprised of 18 genotypes, cluster II ten genotypes, cluster IV two genotypes whereas clusters III, V and VI comprising of one genotype each. The

characters LLS score at 70 DAS and test weight contributed the maximum towards genetic divergence in D^2 analysis. Based on inter-cluster distances, the clusters IV and V were adjudged as the most divergent clusters. The genotypes ISK-04-26(IV) is highly resistant in late leaf spot disease whereas the genotype ISK-04-11(V) recorded the highest plant height and high yield as well. Hence, genotypes in these clusters namely ISK-04-26 and ISK-04-11 were suggested for inclusion in hybridization programme for obtaining superior and desirable recombinants having high resistance to LLS coupled with high yield.

Character association studies indicated the significant positive correlation of pod yield per plant, shelling percentage, plant height, sound mature kernel per cent, test weight and harvest index with kernel yield and also among themselves. Path co-efficient analysis revealed that pod yield per plant, shelling percentage, plant height and sound mature kernel per cent are important yield components having direct bearing on the improvement of kernel yield in groundnut.

RAPD analysis detected a moderate level of genetic variation among the ten genotypes of groundnut selected from different clusters formed from D^2 analysis. A high degree of polymorphism was obtained with the primer OPH 20(5 polymorphic bands) whereas moderate polymorphism was obtained with the primers OPA 3(5 polymorphic bands), OPA 5(3 polymorphic bands), OPJ 4(2 Polymorphic bands) and OPJ 12(2 polymorphic bands). The similarity index values ranged from 0.500 to 1.00 indicating a moderate range of variability at the molecular level in case of groundnut. M.Sc.(2007).

Studies on Combining Ability and Heterosis in Confectionery Types of Groundnut (*Arachis hypogaea* L.*)*

Student: Saraswathi M. Major Advisor: Dr. O. Venkateswarlu

Department of Genetics and Plant Breeding

The present study was under taken with the objective of identifying the best parental genotypes and cross combinations and to conceptualise breeding strategy for yield and quality improvement in confectionery groundnut. An experiment consisting of three lines, (ICGV-99157, K-4 and TAG-24), five testers (TG-47, TKG-19A, BAU-13, ICGV-86564 and JSS -HP-21) and 15 F_1 crosses was laid out at R.A.R.S., Tirupati during *Kharif,* 2006. The hybrids were produced by crossing in line x testers design. The data recorded for kernel yield and its component characters were subjected to study on combining ability, heterosis, character association, path analysis, variability and genetic parameters.

The highest magnitude of heterosis was observed for number of primary branches per plant, number of filled pods per plant, shelling percentage, SMK percentage, total sucrose content, pod yield and kernel yield per plant.

Kernel yield was found to be significant and positively correlated with number of primary branches per plant, number of filled pods per plant, harvest index, shelling percentage, protein content, total sucrose content and pod yield per plant.

A perusal of genetic parameters revealed high GCV, PCV, high heritability coupled with high genetic advance as percent mean for number of primary branches per plant, plant height, total sucrose content, pod yield and kernel yield per plant indicating that there traits can be improved by simple selection method. M.Sc.(2007).

ABSTRACTS

Biological Control of *Colletotrichum gloeosporioides* Penz, Causing Mango Anthracnose and Molecular Characterization of Potential Biocontrol Agents

Student: Anu Anie Mathews Major Advisor: Dr. N.P. Eswara Reddy

Department of Plant Pathology

Anthracnose caused by *Colletotrichum gloeosporioides* is an important disease of mango causing 30-60% losses especially in humid climate. Several reports suggest the development of resistance by the pathogen to different fungicides. Hence in the present study, an attempt was made to isolate native potential antagonists against *C. gloeosporiodes* causing anthracnose of mango and to evaluate their efficiency in combinations with different fungicides both under *in vitro* and *in vivo.*

A total of 24 antagonistic microflora (15 fungi and 9 bacteria) were obtained from phylloplane and fructoplane of mango using leaf/fruit wash method.

Sensitivity of *C.gloeosporioides* to different fungicides *viz.,* carbendazim, hexaconazole, propiconazole, prochloraz, thiophanate-methyl, captan, thiram, mancozeb and copper oxychloride were assessed in poisoned food technique. All fungicides, except mancozeb inhibited the pathogen completely.

Compatibility of the three potential fungal antagonists *viz.,* T_1, T_7 and F_{11} with above said fungicides were evaluated in poisoned food technique and bacterial isolate B_1 using spectrophotometric method. F_{11} isolate was incompatible with all fungicides except mancozeb. B_1 isolate gave very low OD values at 600 nm compared to control in case of hexaconazole, captan, thiram and copper oxychloride indicating its incompatibility with those fungicides. T_1 and T_7 isolates were 100% per cent compatible with mancozeb, but gave different degrees of compatibility with other fungicides. T_7 was compatible with thiram (76.44%), whereas T_1 was incompatible (18.11%). Based on its high inhibition per cent and relatively higher compatibility with thiram, T_7 isolate was selected as the best potential fungicide compatible antagonist.

Based on *in vitro* results, the inhibition of *C.gloeosporioides* by *T. fasciculatum* may be due to combined action of competition due to fast growth, production of volatile and non-volatile metabolites and mycoparasitism.

The molecular characterization of nine potential *Trichoderma* isolates using RAPD with five random primers *viz.,* OPA3, OPA5, OPA8, OPA9 and OPA10 gave high polymorphism. All the five primers produced unique bands in case of *T. koningii.* However, the primer OPA8 amplified a unique band of approximately 800 bp in case of *T.fasciculatum.* All the isolates were classified into three clusters based on dendrogram formed using UPGMA analysis. In ITS-PCR all the isolates produced a single band ranging from 560 to 657 bp which confirmed the generic status of *Trichoderma.* M.Sc.(2007).

Management of Tomato Wilt Incited by *Fusarium oxysporum f.sp.lycopersici(*Sacc.) and Molecular Characterization of Potential *Trichoderma spp.*

Student: R. Venkateswarlu Major Advisor: Dr. M. Reddi Kumar

Department of Genetics and Plant Pathology

Tomato(*Lycopersicon esculentum* Mill.)is a widely grown vegetable crop acquiring the status of world's most popular vegetable due to its importance for nutritive value, processing and export potential. Tomato is affected by many diseases among which wilt caused by *Fusarium oxysporum* f.sp. *lycopersici* is one of the important disease, resulting in 10-50 per cent yield loss around the world. *Fusarium oxysporum* f.sp. *lycopersici* is a serious soil-borne pathogen and persists for longer periods in the soil.

Among all antagonistic mycoflora isolated from rhizosphere soil of tomato plants, *Trichoderma virens*(T_2 isolate) inhibited pathogen growth to a maximum extent of 81.11 per cent.

In vitro efficacy of foru fungicides *viz.,* carbendazim, thiophanatemethyl, mancozeb and thiram were evaluated against *F.oxysporum* f.sp. *lycopersici* using poisoned food technique at 3 concentrations *viz.,* 250, 500 and 1000 ppm. Carbendazim was found to be effective as it inhibited pathogen growth to a maximum extent of 77.95 per cent. Thiophanate-methyl was found to be next best fungicide.

The efficacy of effective antagonist *Trichoderma virens*(T_2 isolate) and fungicide(mancozeb) was tested in pot culture against wilt pathogen *F. oxysporum* f.sp. *lycopersici* in tomato. The results revealed that treatment T_8 (seed treatment with T_2 isolate @ 4gh+mancozeb @ 2 g kg^{-1} seed) was found to be superior which recorded least pre-emergence and post-emergence per cent disease incidence (4.00 and 9.50%) and maximum plant height(26.70cm) and root length (9.59cm) when compared to all other treatments.

Genetic variability among the isolates of *Trichoderma* Spp. was studied using molecular techniques like RAPD and ITS-PCR. The RAPD banding pattern reflected the genetic diversity among the isolates with the formation of 7 clusters. ITS region of rDNA amplification with genus specific ITS 1 and ITS 4 universal primers produced product size varies from 504 to 566 bp in all the isolates indicated polymorphism at ITS region of rDNA among the *Trichoderma* isolates. M.Sc.(2007).

Extent of Spread of Heavy Metal Contamination in Municipal Dump Environs in Tirupati, Andhra Pradesh

Student: M. Prabhavathi Major Advisor: Dr. Kotu Sreenivasulu Reddy

Department of Soil Science and Agricultural Chemistry

Studies on The present investigation Contamination in Municipal Dump was conducted with the objective of assessing the effect of municipal dump environs on soil properties, ground water qualities, nutrient status of index leaf, uptake by whole plant and crop yield losses at different distances from the municipal dump environs.

The ground water from bore wells at different lateral distances and soil samples at 0, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000m distance from the municipal dump environs were collected and analysed for different properties in the year 2006. The crops yield losses in the farmers fields around municipal dump environs were also recorded.

The composition of municipal waste in terms of pH, EC, N, P, K, Ca, Mg, Na micronutrients (Fe, Mn, Zn and Cu) and heavy metals(Cd, Cr, Ni and Pb) was relatively more as compared to that of ground water adjoining municipal dump environs.

The soil properties like EC, OC, N, P, K, Ca, Mg, S, CO_3^{--}, HCO^-_3, $C1^-$, micronutrients *viz*, Fe, Mn, Zn and Cu and heavy metals viz., Cd, Cr, Ni and Pb were significantly more in the immediate vicinity of the municipal dump environs. Due to municipal dump environs, the concentration of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Cd, Cr, Ni and Pb in the index leaf and uptake by rice collected during study periods were slightly higher in the immediate vicinity of the municipal dump environs as compared to the farther distances. The adverse effects of municipal dump environs on rice were continued upto 200m.

There is a need to take up legislation regarding the disposal of municipal wastes, so as to maintain sufficient distance from agricultural fields, drinking / irrigation water sources and human habitations. M.Sc.(2007).

Effect of Integrated Phosphorus Management of Yield and Quality of French Bean

Student: P. Venkata Subbaiah Major Advisor: Dr. Keerthi Venkaiah

Department of Soil Science and Agricultural Chemistry

A field experiment was conducted during *rabi*, 2006 on sandy loam soils (Typic Haplustulf) of dryland farm of Sri Venkateswara Agricultural College, Tirupati to evaluate the influence of integrated phosphorus management on yield and quality of French bean.

The effect of integrated nutrient sources on soil physico-chemical and chemical properties, drymatter production, pod yield, quality parameters, nutrient concentration and nutrient uptake was studied during the present investigation.

Integrated phosphorus sources and RDF did not have significant influence on physico-chemical properties of soil *i.e.* pH, EC except organic carbon and CEC. Soil organic carbon and CEC increased with the application organic manures (PM or VC) and RDF coupled with treating the soil with phosphobacteria over RDF and other treatments after final harvest of French bean.

The drymatter production and pod yield was significantly influenced by varied combination of treatments. The drymatter production and pod yield with 80% RDF+ 20% P through PM+PB @ 2.5kg ha^{-1} and 80% RDF+20% P through VC +PB @ 2.5kg ha^{-1} recorded significantly superior to other treatments tried in this study.

Pod quality attributes *i.e.* protein content and fibre content differed significantly among the integration of various sources of nutrients. Application of 80% RDF+20% P through PM+PB@2.5 kg ha^{-1} and 80%

RDF+20% P through VC+PB@ 2.5 kg ha^{-1} recorded significantly highest protein content over other treatments whereas fibre content was maximum with 50% RDF+PB@ 2.5 kg ha^{1} over other treatments.

Influence of integration of varied sources of nutrients differed significantly on concentration of N, P, K, Ca, Mg, S and micronutrients at all growth stages of the crop, Significantly maximum concentration of nutrients were recorded with application of 80% RDF+20% P through PM+PB@ 2.5 Kg ha^{-1} and 80% RDF+ 20% P through VC + PB @ 2.5 kg ha^{-1} these two were superior to all other treatments tried in this study.

Uptake of nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) differed significantly among the varied combination of sources of nutrients at all the growth stages of the crop, Significantly higher uptake of nutrients were recorded with 80% RDF + 20% P through PM+PB @ 2.5 kg ha^{-1} and 80% RDF+20% P through VC+PB @ 2.5 kg ha^{-1} over RDF and other treatments.

Finally, it is concluded that integrated use of balanced chemical fertilizers(Urea, SSP and MOP) and organic sources of nutrients (PM or VC) coupled with biofertilizers (phosphate solubilizing bacteria) enhances the French bean productivity improving nutrient use efficiency and sustains the fertility status of alfisols. M.Sc.(2007).

Genesis, Classification and Evaluation of Soils in Vadamalapeta Mandal of Chittoor District, Andhra Pradesh

Student: Y.S.Satish Kumar Major Advisor: Dr. M. V. s. Naidu

Department of Soil Science and Agricultural Chemistry

The present investigation was carried out to study the genesis, classification and evaluation of soils in Vadamalapeta mandal of Chittoor district in Andhra Pradesh. For this seven representative pedons were selected in seven different locations of the study area covering all types of soils. All the seven pedons were described for their morphological features in field and horizon-wise samples were collected and analyzed in the laboratory for physical, physico-chemical and chemical properties.

The morphological features revealed the presence of AC(Pedons 2,3,5 and 6) and ABC(Pedons 1, 4 and 7) profiles. The soils were moderately deep to very deep in depth, very dark grayish brown to red in colour, sandy to clay in texture and had sub-angular blocky, angular blocky and single grain structure.

The clay content increased with depth in pendon 7 whereas pedon 4 showed an increasing trend upto fourth horizon and later on a decreasing trend with depth. Pedons 1, 2, 3, 5 and 6 have shown no specific trend with depth. Physical constants like water holding capacity, loss on ignition and volume expansion followed the trend of clay content. Most of the pedons showed more or less an increasing trend of bulk density with depth, corresponding to decreasing organic carbon content with depth.

Regarding nutrient status, the soils were low to medium in available nitrogen and phosphorus, low to high in available potassium and high in available sulphur. However, soils were deficient in available iron and sufficient in available zinc, copper and manganese.

The soil-site suitability evaluation revealed that all the pedons in the study area were marginally suitable (S3) for growing rice crop. Pedons 1, 2, 3 and 7 were moderately suitable while pedons 4, 5 and 6 were marginally suitable for growing groundnut crop. However, pedons 1, 2, 3 and 5 were moderately suitable (S2) whereas pedons 4, 6 and 7 were marginally suitable (S3) for growing sugarcane crop. M.Sc.(2007).

Effect of Biofertilizers on Growth, Yield and Quality Parameters of French Bean (*Phaseolus vulgaris* L.)

Student: V. Ramana Major Advisor: Dr. M. Ramakrishna

Department of Horticulture

A field study was conducted at the Horticultural garden, S.V. Agricultural College, Tirupati to study the effect of biofertilizers on growth, yield and quality parameters of french bean(*Phaseolus vulgaris* L.) using the cultivars Arka komal, Arka Suvidha and Selection - 9.

The experiment was laid out in randomized block design with factorial concept with four treatments and three varieties replicated thrice. Method of application of biofetilizers was soil application.

Plant height, number of branches and number of leaves were maximum with the application of 75 per cent RDF in combination with Vescicular arbuscular micohorizhae (VAM) @ 2 kg ha^{-1} and phosphorus solubilizing bacteria (PSB) @ 2.5 kg ha^{-1} followed by 50 per cent RDF+VAM @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1} in the variety Arka Suvidha and least was recorded in Arka Komal. Interaction effect was significantly different between varieties and treatments.

The yield attributing characters like number of clusters per plant, number of pods per plant, number of pods per cluster, number of seeds per pod, length of pod(cm), 100-seed weight(g), pod yield per plant (g $plant^{-1}$), pod yield per hectare (t ha^{-1}) were increased by the application of 75 per cent RDF in combination with VAM @ 2 kg ha^{-1} and PSB @ 2.5 kg ha^{-1} in the variety Arka Suvidha followed by Selection -9 and Arka Komal.

Least per cent crude fibre and maximum per cent crude protein was observed in the variety Arka Suvidha followed by Selection - 9 and Arka Komal with the treatment 75 per cent RDF+VAM @ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} and maximum interaction effect was recorded between varieties and biofertilizers.

Highest benefit cost ratio, gross returns and net returns was recorded with the treatment 75 per cent RDF + VAM @ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} in variety Arka Suvidha, due to higher yields.

From the present study, it is concluded that application of biofertilizers (VAM @ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1}) in combination with inorganic fertilizer (75% RDF) could increase the growth, yield attributes, yield and quality with reduction in the cost of cultivation and increased the net profit in french bean variety Arka Suvidha. Hence, such biofertilizer management practices would be best suitable for southern agro climatic zone of Andhra Pradesh. M.Sc.(2007).

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