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HYBRID TECHNOLOGY–A NEW VISTA IN PIGEONPEA BREEDING

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1. Introduction

Once designated as an 'orphan crop' to now being crowned as a mainstream 'commercial crop', pigeonpea has evolved over the decades as lifeline for millions of resource poor farmers in the semi-arid tropics, where it is cultivated for both subsistence and commercial purpose.Pigeonpea [*Cajanus cajan* (L.)] is the sixth most important legume crop, grown predominantly in the tropical and sub-tropical regions of Asia, Africa and Latin America. India is considered as the center of origin of pigeonpea (Van der Maesen, 1980) because of its natural genetic variability available in the local germplasm and the presence of its wild relatives in the country.

The global pigeonpea area, production and yield was approximately 6.23 m ha, 4.74 M T and 762.4 Kg ha^{-1}, respectively (FAOSTAT, 2015). The major producers of pigeonpea are India (63.74% of global production), Myanmar (18.98%), Malawi (6.07%), Tanzania (4.42%) and Uganda (1.98%). In India pigeonpea was cultivated on 5.06 M ha with a total production of 3.29 M T and yield of 649.9 Kg ha^{-1} during 2014 (FAOSTAT, 2015). The leading states in pigeonpea production are Maharashtra (0.259 M T), Karnataka (0.51 M T), Madhya Pradesh (0.39 M T), Uttar Pradesh (0.259 M T), Gujarat (0.258 M T) and Jharkhand (0.19 M T). These six states account for 84% of the total production in India during 2014-15 (E-Pulse Data Book, 2016).

Pigeonpea is a hardy, widely adapted and drought tolerant crop. It has a range of maturity which helps in its adaption in a wide range of environments and cropping systems. It can be grown either as sole crop or intercrop with urd bean, mung bean, castor, sorghum, soybean, cotton, maize and groundnut. Pigeonpea is mostly consumed as dry split dal. It is an excellent source of protein (20-22%), supplementing energy rich cereal diets in a mainly vegetarian population. The per capita net availability of pulses in India has reduced from 51.1 g day^{-1} (1971) to 41.9 g day^{-1} (2013) as against WHO recommendation of 80 g day^{-1}. According to Indian Institute of Pulses Research (IIPR) estimation, India's population is projected around 1.68 billion by 2030 pulse requirement around 32 million tones.

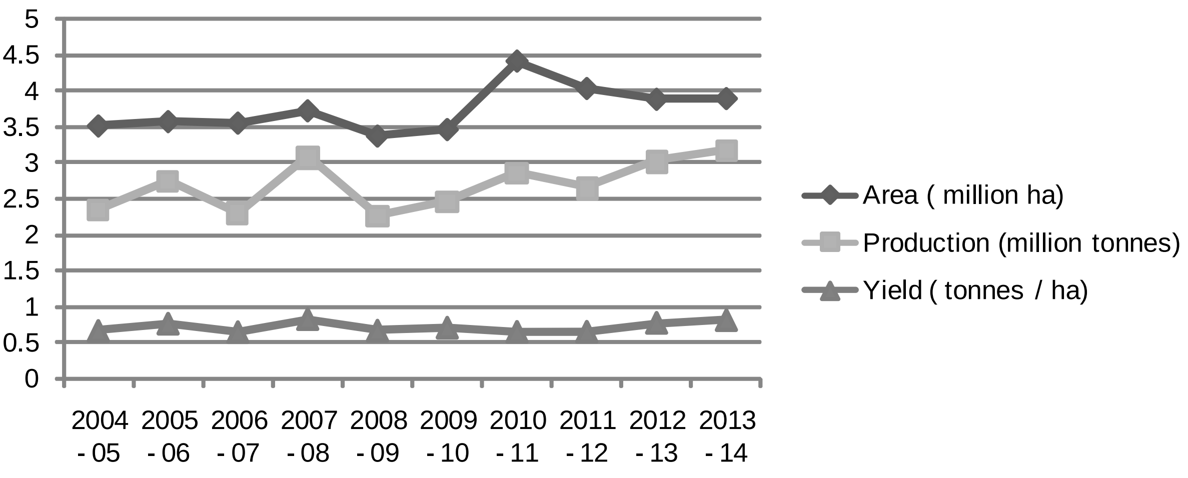


Fig 1. Area, Production and Yield of Pigeonpea over the last decade in India.
(Source: E- Pulse Data Book, IIPR Kanpur, 2016)

The wide difference between production and demand of pulses has resulted in lager imports in recent past (2012-13) reaching a record 4.0 million tons an increase of 500,000 tons over 2011-12 (India's Pulses scenario 2014). Pigeonpea has been in focus in recent times due to the continuous inflation in its price. Stagnant productivity coupled with declining availability has created substantial supply & demand gap forcing heavy import bill on the exchequer and affecting nutritional security of majority of the population for whom pulses are one of the cheapest source of protein. Thus, this review in the backdrop of 'International Year of Pulses' attempts to give a bird's eye view of the advent of hybrid pigeonpea technology, which played a pivotal role to in breaking the yield plateau and achieving the quantum leap in its production.

2. Early Research:

To promote pigeonpea production, genetic improvement of pigeonpea was emphasized by researchers for more than five decades and a number of cultivars were developed from selection of land races (Singh *et al.,* 2005). However, the progress in the genetic improvement of yield potential was limited and the improved cultivars enhanced the productivity to some extent.Therefore, an alternative breeding approach i.e., hybrid technology, was attempted in pigeonpea to enhance the yield.

2.1 Gene action and Heterosis

In crops where high yielding commercial hybrids have been developed, the breeders have reported that additive and dominance gene actions are predominantly responsible for the expression of hybrid vigour for yield. Very limited research has been done on the genetic aspects of various agronomic traits in pigeonpea. Sharma and Green (1975) concluded that the important agronomic characters are controlled primarily by genes with additive effects. Dominance and non additive effects were also detected for yield, plant height and protein content.

Table 1. Estimates of gene effects in pigeonpea for vegetative characters

Character(s)	Genetic variance(s)	Reference (s)
Days to flowering	Additive	Dahiya and Barar, 1977.
Flower initiation	Additive	Venkateswarlu and Singh, 1982.
Plant height	Predominantly additive	Singh and Pandey, 1974.
	High GCA than SCA thus more additive	Sharma *et al.,* 1973b.
	Additive	Singh *et al.,* 1983b.
	Single recessive (d) gene for dwarf height	Sen *et al.,* 1966.
Plant growth	Predominantly additive	Singh and Pandey, 1974.
Early maturity	Additive Partial dominance, A × D	Dahiya and Satija, 1978.
		Mohamed *et al.,* 1985.
Days tomaturity	Additive Non additive	Sidhu and Sandhu, 1981.
		Patel *et al.,* 1987.
Leaf area	Additive	Sharma and Saxena, 1983.
Leaf mass	Additive	
Petiole length	Additive	
Petiole mass	Additive	
Fruiting branches	Additive	Singh *et al.,* 1983b.
Raceme length	Additive	

(Source: Singh and Oswalt, 1992.)

Table 2. Estimates of gene effects in pigeonpea for productivity characters

Character(s)	Genetic variance(s)	Reference (s)
Pods plant^{-1}	Non-additive (over dominance) Both additive and non-additive Additive	Dahiya and Barar, 1977. Venkateswarlu and Singh, 1982. Singh *et al.,* 1983b.
100 seed mass	Non- additive (over dominance) Additive Both additive and non-additive A×A&D×D	Dahiya and Barar, 1977. Sidhu and Sandhu 1981. Venkateswarlu and Singh, 1982. Mohamed *et al.,* 1985.
Seed yield	Non-additive (over dominance) Predominantly non-additive Higher GCA than SCA thus additive Non-additive Both additive andnon-additive	Dahiya and Barar, 1977. Singh and Pandey, 1974. Sharma *et al.,* 1973b. Dahiya and Satija, 1978. Venkateswarlu and Singh,1982.
Seed size Protein content	Additive, partial dominance of small seed Non-additive Both additive and non-additive	Singh and Pandey, 1974. Singh and Pandey, 1974. Sharma *et al.,* 1972.
Early maturity	Additive Partial dominance, A&D	Dahiya and Satija, 1978. Mohamed *et al.,* 1985.
Pod width	Additive	Sidhu and Sandhu, 1981.
Seeds pod^{-1}	Both additive and non-additive Dominance, A × D& D × D	Venkateswarlu and Singh, 1982. Mohamed *et al.,* 1985.

(Source: Singh and Oswalt, 1992).

Heterosis is a natural phenomenon which makes hybrid off spring of genetically diverse individual and display improved physical and functional characteristics relative to their parents (Coors and Pandey 1997; Shull 1948). Heterosis in crops can be perceived in the form of increased growth rate, total biomass, stress resistance, seed yield and population fitness (Kalloo *et al.,* 2006). Heterosis is largely universal and can result in quantum leap in yield by 15-50% depending on crop type. Many major cereal crops as well as commercial varieties of vegetables and flower crops are cultivated using hybrid seeds for increased agricultural performance (Duvick 1999; Birchler *et al.,* 2003).

Heterosis was first utilized in maize (*Zea mays*), followed by other crops (Melchinger and Gumber,1998). Yield advantage in maize, rice, wheat and grain sorghum owing to hybrid vigour were around 15% (Duvick 1999), 20-30% (Cheng *et al.,* 2007), 10-25% (Hoisington *et al.,*1999) and 35-40% (Duvick, 1999), respectively in USA and Asian sub-continent. In pigeonpea, significant heterosis was also reported by Kumar and Srivastva (1998), Pandey and Singh (2002), Wankhade *et al.,*(2005), Baskaran and Muthiah (2006), Dheva *et al.,*(2009),Chandirakala*et al.,*(2010), Vaghela *et al.,* (2011), Pandey *et al.,* (2013) and Kumar *et al.,*(2015).

2.2 Mechanism of Natural out-crossing in Pigeonpea

The first report of natural out-crossing in pigeonpea was in 1919 (Howard *et al.,*1919) wherein, they found 14% out crossing. Studies were conducted to understand the factors responsible for out crossing in this crop and frequent insect visits was the main cause (Pathak 1970; Williams 1977; Onim 1981; Zeng-Hong *et al.,*2011).These studies revealed that over two dozen insect species were found foraging on pigeonpea flowers, but out crossing was affected only by few. Williams (1977) reported that *Megachile bicolor* and *M. conjuneta* were the major pollinators, while Onim (1981) reported cross pollination in pigeonpea was mainly a function of foraging by *Apis millifera* and *Megachile* species in Kenya. Lately, Zeng- Hong *et al.,* (2011) found that in Yuanmou (China) the insects belonging to *Megachile spp., Xylocopa* and *Apinea* were most frequent visitors to pigeonpea fields and they were very active in collection and transportation of pollen grains from one plant to another, thereby, resulting in cross- fertilization.

Over the period, population of pollinating insect tend to fluctuate across the locations and time of the year resulting in natural out crossing (Saxena *et al.,*1990). Moreover, some external factors are also known to affect the extent of out crossing like speed and direction of wind (Bhatia *et al.,*1981), extended periods of stigma receptivity (Dalvi and Saxena 2009) and floral morphology of geno type (Byth *et al.,*1982).

3. Dawn of heterosis breeding era in pigeonpea

The first pigeonpea variety was developed for wilt resistance by selection in land races (Shaw 1933). Subsequently, more than 100 pureline pigeonpea varieties were released for cultivation over the past seven decades (Singh *et al.,* 2005) resulting in substantial increase in area & production, but productivity showed little increment. This encouraged breeders to move towards heterosis breeding for harnessing the inherent heterotic potential for breaking the yield plateau, as no further horizontal increase in area under pigeonpea was possible. For economically viable hybrid seed production system, hand emasculation and pollination is not commercially feasible. Hence, development of stable male sterile line became imperative for utilization of available natural out crossing in pigeonpea.

4. Male Sterility Systems

Plants that fail to produce functional pollen grains are male sterile and such plants reproduce only when fertile pollen from other plants falls on their stigmatic surface through any mechanical means. The first report of male sterility came in 1763 (Kolreuter, 1763).The male sterility is controlled by specific genetic factors which are generally recessive in nature. Such genes are exposed during inbreeding and their maintenance is affected by fertilization with the pollen that carries corresponding dominant gene(s).

In plant system, the male sterility is generally caused by some specific bio-chemical events that hinder normal biological processes of pollen production. It is also noticed that all the male-sterility systems identified so far in different crops could not be used in hybrid breeding programmes because of non- availability of other complementary genetic systems required for restoring their male fertility. For efficient utilization of male sterility system in heterosis breeding, it is necessary that the expression of both male-sterility and male fertility restoration systems are stable over the years and locations. A perfect male sterility in the female parent in conjunction with natural out-crossing makes the hybrid seed production easy and affordable. For crops where seed is of economic value, either Genetic Male Sterility (GMS) or Cytoplasmic Genetic Male Sterility (CGMS) system can be used.

4.1 Genetic Male Sterility (GMS) System

This system of sterility is the first break through in hybrid seed production of redgram and it arises when male fertility controlling dominant (Fr) nuclear gene mutates to its recessive form under the influence of some natural forces and with subsequent natural selfing of heterozygotes (Frfr) the male sterile genotypes (frfr) appear within the population. Such genotypes if not cross pollinated by fertile pollen are eliminated from its parental population. An elaborate search for male sterility system in pigeonpea was flagged off in 1970's and resulted in the discovery of GMS system. The first report on male sterility in pigeonpea was documented by Deshmukh (1959). Reddy *et al.,* (1977) made an extensive search on CGMS system in 7216 germplasm accessions sown in ICRISAT in 1974, but instead a source of GMS was identified in a field collection from Andhra Pradesh. This GMS line was medium duration (180 days maturity) and susceptible to fusarium wilt and sterility mosaic disease. The male sterility was controlled by single recessive gene 'ms_1' which arose spontaneously (Reddy *et al.,* 1978). The male sterile lines derived from ms_1 source were extensively used in breeding program at ICRISAT and ICAR institutes. The outcome of this effort was release of world's first pigeonpea hybrid ICPH8 in1991 (Saxena *et al.,*1992). It was found superior to national checks UPAS120 and Manak by 30.5% and 34.2%, respectively.

hybrids. Correns (1908) reported that cytoplasmic factors could influence occurance of male sterility and the trait would be maternally inherited.

Nagur and Menon (1974) studied several of these sources and recognized four different classes based on fertility/ sterility responses in hybrids. These were further studied by Reddy (1992) in an effort to classify them and to find minimum differential testers. These were designated as A_1 (CK60; origin-East Africa), A_2 (IS 12662C; origin-Ethiopia), A_3 (IS 1112C; origin-India) and A_4 (M35-1, VZM2 and G1; origin-India).

Table 3. List of Genetic Male Sterile hybrids of pigeonpea released in India

Hybrid	Origin	Year	Adaptation zone	Maturity group	Standard heterosis (%)	Year of release
ICPH 8	ICRISAT	1991	Central	Early	35	1991
PPH 4	PAU, Ludhiana	1994	North west	Early	14	1993
CoH 1	TNAU, Coimbatore	1994	South	Early	21	1994
CoH 2	TNAU, Coimbatore	1997	South	Early	35	1997
AKPH 4104	PKV, Akola	1997	Central	Early	64	1997
AKPH 2022	PKV, Akola	1998	Central	Medium	30	1998

4.2 Cytoplasmic Genetic Male Sterility (CGMS/ CMS) System

Considering the shortcomings in large scale hybrid seed production in GMS hybrids, the development of cytoplasmic nuclear male sterility became imperative. CGMS is a physiological abnormality, resulting from a disharmonious interaction between the cytoplasmic factors and nuclear genetic factors, leading to the production of degenerated or non-viable pollen grains or non-dehiscent anthers with or without functional pollen grains. Kolreuter (1763) first noticed cytoplasmic genetic male sterility in interspecific and intraspecific

Table 4. List of CMS systems in wild species of pigeonpea

Wild species	CMS System	Remarks
C.sericeus	A1	CMS sensitive to temperature
C. scarabaeoides	A2	Fertility restoration unstable
C. volubilis	A3	Large variation in expression
C.cajanifolius	A4	Stable and used in hybrid program
C.cajan	A5	Uses cultivated pigeonpea cytoplasm
C. lineatus	A6	CMS system very stable
C. platycarpus	A7	A new CMS using tertiary gene pool
C. reticulates	A8	Searching for restoration in progress

5 (a). First CMS-based pigeonpea hybrid GTH-1

The first CMS-based pigeonpea hybrid GTH-1 was developed at GAU, SK Nagar and released by ICAR in 2004 for cultivation in Gujarat. This hybrid was bred by crossing A_2 CMS line GT 288A with fertility restorer GTR-11. Based on multi-location yield trials conducted during 2000 to 2003, GTH-1 (average yield 1830 $Kgha^{-1}$) gave 32% higher yield over the best local check (GT 100/110 with average of 1330 Kg ha^{-1}). This hybrid is non-determinate type and early maturity (140days). In frontline demonstrations conducted in three districts (2003), the hybrid exhibited 25.3% yield superiority over the popular check. After multi-location trials conducted by ICAR, the hybrid GTH-1 was released for cultivation in central zone.

Table 5. Performance (yield Kg ha^{-1}) of three hybrids in on-farm trials

Hybrid	State	Farmers (no.)	Hybrid yield	Control yield	Standard Heterosis (%)
GTH-1	Gujarat	04	2673	1996	25
ICPH 2671	Maharashtra	782	969	717	35
	Andhra Pradesh	399	1411	907	56
	Madhya Pradesh	288	1460	864	69
	Total / Mean	360	1940	1326	46
		1829	1445	954	51
ICPH 2740	Madhya Pradesh	13	1814	1217	49
	Andhra Pradesh	47	1999	1439	39
	Gujarat	40	1633	1209	35
	Total / Mean	100	1825	1288	41

5 (b). First commercial CMS-based pigeonpea hybrid-ICPH 2671

The first ever commercial hybrid of any grain legume is ICPH 2671. It was produced by crossing a male sterile line ICPA 2043 with restorer ICPR 2671.The plants of ICPH 2671 have semi-spreading habit, non-determinate type and profuse branching. It grows over two meter in height, matures between 164-184 days and contains 3.7-4.0 seeds pod^{-1}. The purple coloured seeds weigh between10.5 to 11.2 $g100^{-1}$ seeds. ICPH 2671 has high resistance to both wilt and sterility mosaic diseases. In comparison to inbred cultivarsthe hybrid, by virtue of its greater root mass and depth, possesses greater ability to draw moisture from deeper soil profiles. Its fast root growth also helps inovercoming short spells of early season drought that is often encountered in July-sown rainfed crops. ICPH 2671 also exhibited high survival (88%) under water-logged conditions and this was found to berelated to its ability to utilize stored assimilates through an aerobic metabolism (Sultana *et al.,* 2012).During 2005-2008, ICPH 2671 was tested in multi-location trials and its mean performance in different years varied from 2200 to 3183 $kgha^{-1}$ andon an average, it gave 47% heterosis over national check Maruti.

5 (c). ICPH 3762

The Odisha University of Agriculture and Technology released ICPH 3762 in 2014, in Odisha state. This hybrid registered 20 to 67 % superiority over check in multi-location testing. In on farm demonstrations over 144 locations it out yielded local check by 124 % superiority. It is resistant to *Fusarium* wilt and Sterility mosaic disease with yield potential of 3.5 to 4 Tons ha^{-1} and is suitable for all soil types of different states in India.

5 (d). ICPH 2740

In 2015, this hybrid was released by PJTSAU (Professor Jayashankar Telangana State Agricultural University), Hyderabad, Telangana State.

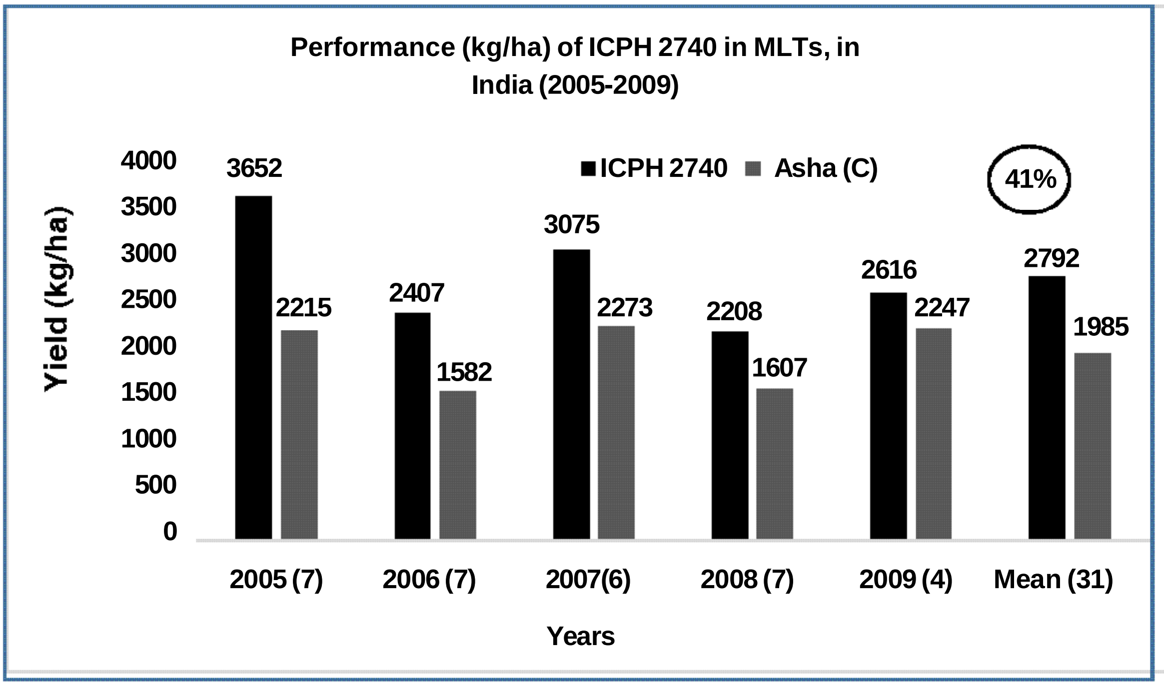


Fig 2: Performance of ICPH 2740 in multi location trials

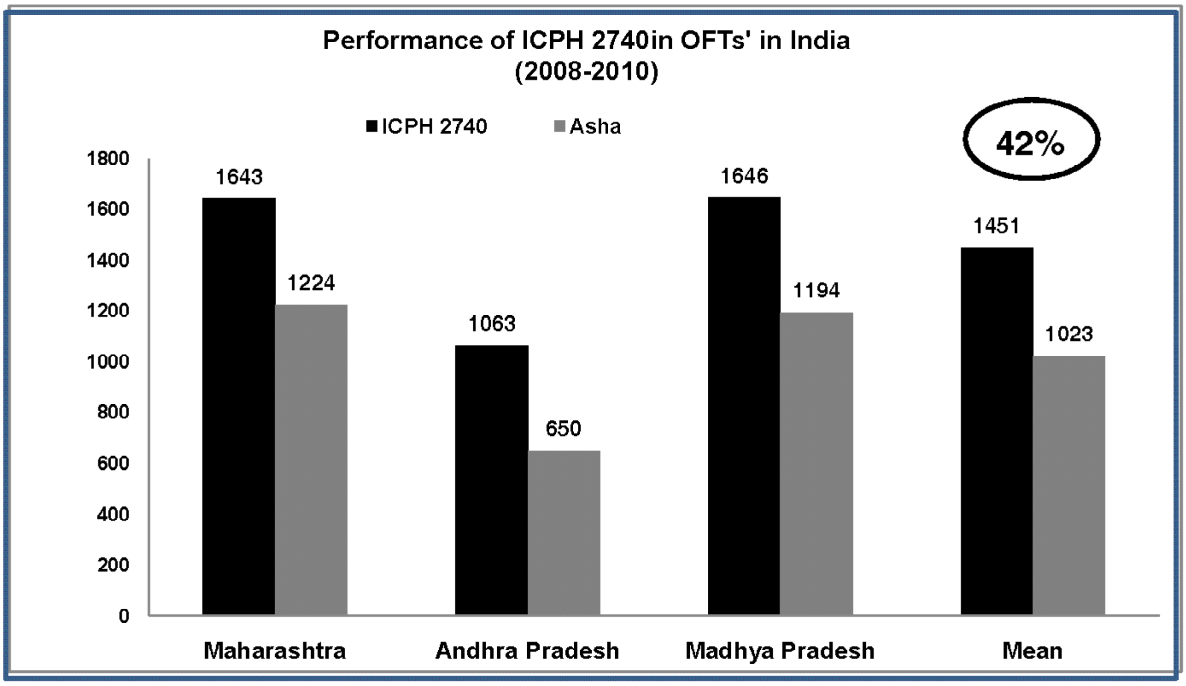


Fig 3. Performance of ICPH 2740 in on farm trials

6. Seed production technology

The benefit of hybrid technology can not be realized unless sufficient quantities of genetically pure hybrid seed is commercially produced and sold at affordable prices. The experiments conducted in various locations revealed that the extent of natural out-crossing (20-70%) in pigeonpea varies considerably (Saxena *et al.,* 1990). The hybrid seed set on the male sterile plants is mainly determined by the availability of bee population in the vicinity of seed production plot. The known prime pollinating agents in pigeonpea are *Megachilelanata, Apisflorae* and *Apismellifera* (Pathak 1970). Onim (1981) reported that each insect visit lasts for 15-55 seconds when they trip the open floral buds, thereby introducing foreign pollen on the stigmatic surfaces to affect cross fertilization. To ensure a good seed set, hybrid seed production plot should be surrounded by bushes that harbour bee colonies and should be located near a water source to maintain high population of pollinating vectors.

6.1 Seed production of hybrid parents

Nucleus seed production of parental lines is an important component of hybrid seed production, since it determines their purity and quality.

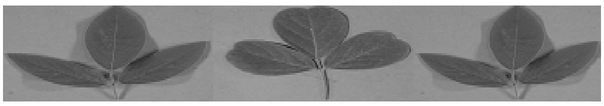
A-line: For seed production of A-line, at initial stages both A and B lines are grown inside insect proof net. Single plants of A and B lines, conforming to the standards of the lines are selected and paired crossed. The crossed seed sets on the A-line plants and selfed seeds on the B-line plants are harvested separately. To produce breeder/ foundation seeds of A-line in large quantities, a field with appropriate isolation distance is selected, A and B-lines are grown with recommended agronomic practices. At ICRISAT, planting ratio of 4 female rows (A-line) and 1 male (B-line) row with staggered sowing at 15 days interval is found to be effective for the production of pure seed of A-line. In short duration A-line, the mature pods on the male sterile and male fertile plants can be harvested by pod picking or by cutting the top pod bearing branches.

B-line and R-line: The nucleus seeds of B and R-lines are produced by sowing pure seed lots of B and R- lines in separate isolations. Hundred plants are to be harvested from the central portion of the seed production plot and their progenies are grown in subsequent seasons. After analyzing their purity aspects, the selected progenies should be bulked to serve as nucleus seed. For breeder and foundation seed production, the lines should be multiplied in separate isolations. Sufficient care should be taken to rouge out the off-types when identified in the field.

Certified seed production: The foundation seeds of A-line and R-line is the source for hybrid seed production. A and R- lines should be sown in 4:1 or 3:1(depending on the bee population) in a staggered planting at 15 days interval in an isolated block. Additional rows of R-line can also be sown on each side of the plot. The pollinating insects visit the male and female flowers randomly and effects pollination and hybridization on the male sterile female lines. The row ratio of female and male lines should be varied according to the environment, insect activity and the time of sowing to ensure good seed set.

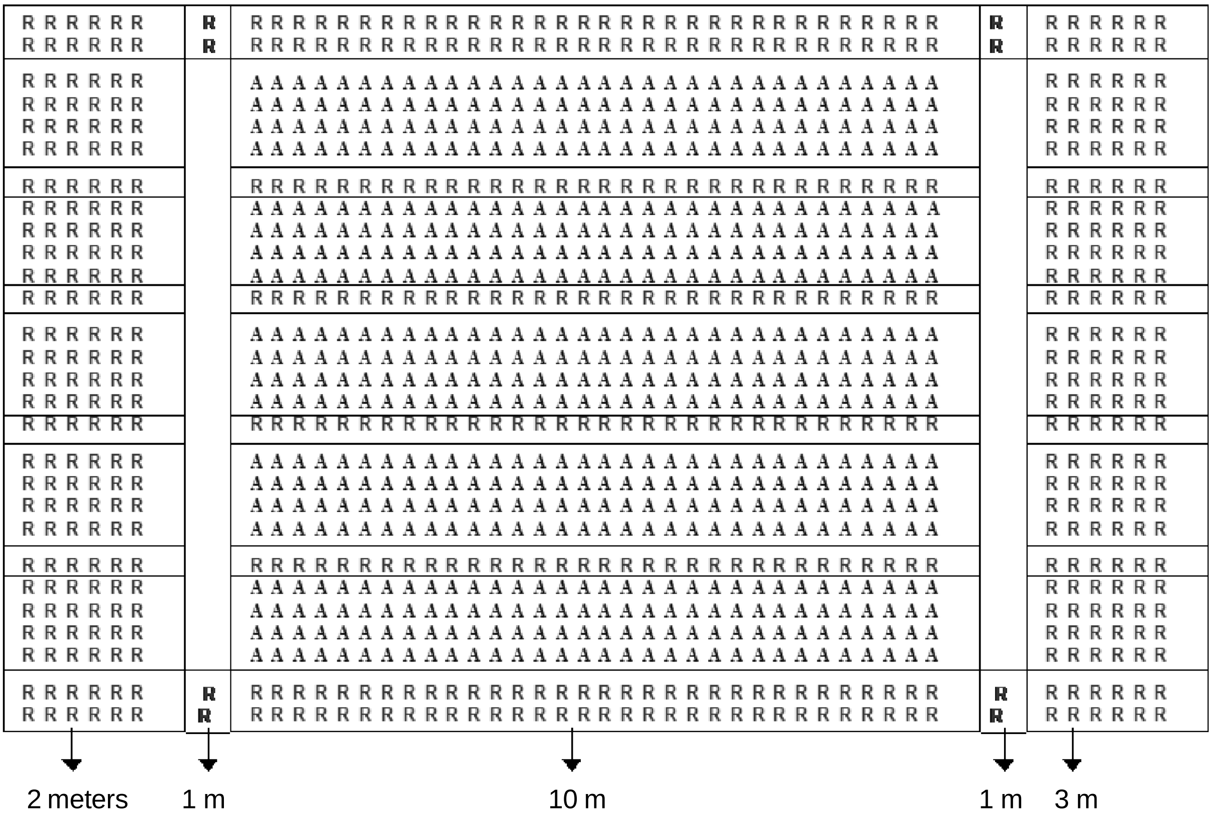
6.2 Breeding of hybrid parents with naked eye polymorphism (NEP)

For grow out test (GOT), it is necessary to have quick assessment system to identify pure hybrid seed. As pigeonpea is grown as an annual crop, days to flowering takes a long time and it is very difficult to conduct a quick GOT. Therefore, some phenotypic markers, which help in easy and efficient identification of pure hybrid seed within a short period of time, are needed. A new approach of using distinct phenotypic trait, that can beidentified by naked eye and called as "naked eyepolymorphic marker" was used to assess purity and identified 'obcordate leaf'' as apolymorphic marker and incorporated it in to A and B-lines.This marker, controlled by a single recessive gene, can be easily recognized within a month after sowing. The hybrids developed by crossing the parents involved normal and obcordate leaf types will always show normal leaves and the unwanted sibs will have obcordate leaves. Such off-types can be detected within a month from sowing. This approach of hybrid breeding should be promoted to help in maintaining seed quality of female parents and hybrids.



R Line **A Line** **Hybrid**

Fig 5. Assessment of parental line and hybrid purity using NEPs



A: A-line (female row)   R: R-line (male row)

Fig 4. A standard field layout for hybrid seed production

7. Genomics: road ahead for pigeonpea breeding

With the availability of reference genome sequences for many important crops and the ability to perform very well through re-sequencing has opened new avenues for proper understanding of the history of plant domestication and to accelerate crop improvement. Crop plant comparative genomics is being transformed by these data thus, a new generation of experimental and computational approach. The future crop improvement programmes will be centred on comparisons of individual plant genome and some of the best opportunities may lie in using combinations of new genetic mapping strategies and evolutionary analyses to direct and optimize the discovery and use of genetic variation. In addition to sequencing of genomes of all legume crops, re-sequencing of large number of genotypes including cultivated and wild genotypes, parental lines, reference sets and released varieties of these legume crops has been initiated at ICRISAT. In case of pigeonpea, whole genome re-sequencing of reference set collection of 292 lines, 104 parental lines of pigeonpea hybrids including cytoplasmic male sterility, maintainer and restorer lines and 21 parental lines of different mapping population has been completed and data analysis is underway (Varshney,2015).

7.1. Hybrid purity test

To enhance the cultivation of pigeonpea hybrids, which has reported significant increase in yield (30-35%) higher yield compared to local varieties, high quality hybrid seeds is the primary requirement. Traditional 'grow-out-test' based on the morphological traits are time consuming and are environment dependent. To overcome this disadvantage, the SSR based hybrid purity kits have been developed for rapid assessment of purityof hybrid and parental lines for two hybrids namely, ICPH 2438 and ICPH 2671 (Bohra *et al.,* 2011; Saxena *et al.,* 2010). Very recently, hybrid seed purity testing kits have also been developed for five more hybrids including one leading pigeonpea hybrid (ICPH 2740) and four promising hybrids (ICPH 4503, ICPH 3762, ICPH 3933 and

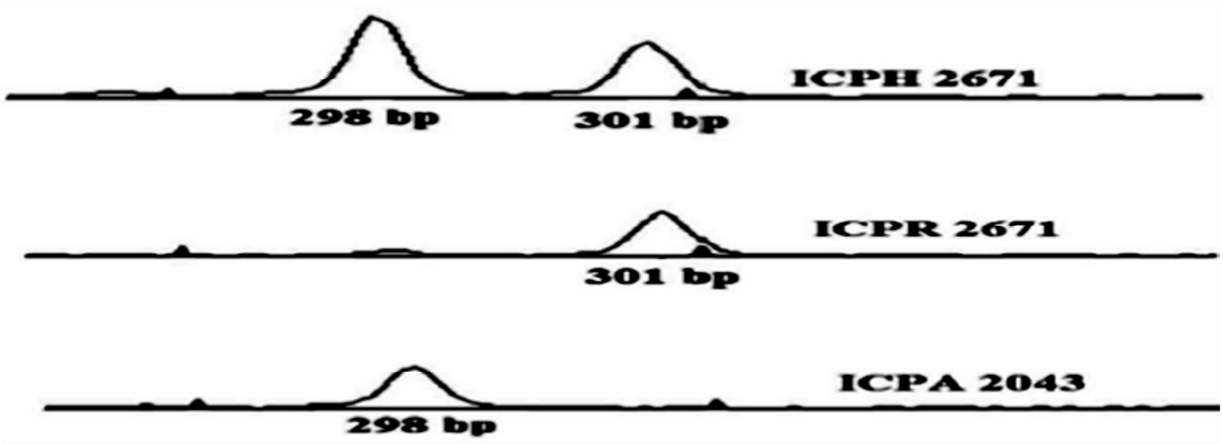


Fig 6. Seed purity assessment of hybrid ICPH 2671 with the CcM 0021 marker.The female line, ICPA 2043 (298bp) and maleline ICPR 2671 (301 bp) show clear peaks using diagnostic SSR marker (CcM 0021, and the true hybrid (ICPH 2671) showed the presence of both the alleles (298 and 301 bp).Sameer Kumar (2015).

ICPH 2751). SSR markers ofthese kits amplify only one specifics allele in their respective parentsand both alleles in their true hybrids. For example, for the hybrid ICPH 2438, SSR marker CCB 4, amplifies 228 bp fragment in ICPA 2039(CMS line or female parent) and 220 bp fragment in ICPR 2438 (male or restorer parent), while the true hybrid (F_1) seeds show both alleles (228 bp and 220 bp). If some seeds of hybrids show only one allele or other allele than the parental genotypes, in such case those seeds are considered as impure hybrid seeds.

In addition to hybrid seed purity testing kit, marker for A4CMS(nad7a del) seed purity has been developed and validated in arange of A4 derived CMS lines and large seed lots. This marker amplifies 150 bp fragment in A4CMS lines and 160 bp fragmentin their cognate maintainer lines and can be visualized on 3.5% agarose gel. The developed CMS associated gene based marker is capable of detection of <2% of adulteration on low-cost agarose gelsystem.

SUMMARY

With the release of three pigeonpea hybrids viz., ICPH 2671, ICPH 3762 and ICPH 2740, the world's first set of commercial hybrids in any food legume, the hybrid technology has become successful. This climate-smart crop can be a boon to farmers as it requires less water, enriches soil, withstands weather variability and is packed with nutrients. In order to sustain the gains of research and development of hybrid technology, its breeding require continuous attention with respect to developing new parental lines. These hybrids have demonstrated their significant superiority in farmers' fields for three consecutive years or more and are now available for general cultivation in India. To sustain the achievements of this breakthrough, it is essential that superior hybrids are made available from time-to-time to the farmers of different regions and to achieve this, development of potential parental lines is an important pre-requisite. Pigeonpea is a new crop as far as hybrid technology is concerned and therefore, development of potential hybrids with easy seed production techniques in this crop needs special attention. Exhaustive research in public-private-partnership mode in tandem with government support is essential for realizing the dream of self-sufficiency in pigeonpea.

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MOLECULAR MARKER ANALYSIS OF A QTL REGION FOR GRAIN SIZE IN BASMATI RICE

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ABSTRACT

Basmati rice is a unique varietal group possessing unique grain quality traits. Breeding of new varieties having Basmati grain quality characters can be greatly facilitated by the use of molecular markers tightly linked to these traits. Hence, in the present investigation 155 recombinant inbred lines (RILs) developed from a cross between Basmati 370 and Jaya were used for molecular analysis of a major QTL for grain size in Basmati rice identified in F_2 population. For this study, SSR and InDel markers present in and around the QTL region were used. Transgressive segregants of 45.8% for grain length, 21.93% for grain breadth and 12.25% for LB ratio were observed. All the three traits exhibited normal distribution indicating quantitative inheritance of these traits. Correlation analysis revealed a high significant negative association of grain length-breadth ratio with grain breadth and significant positive correlation with grain length. Out of 53 markers used, 23 (43.40%) markers were polymorphic among the parents. QTL mapping study revealed a minor QTL, *qGL5.1* in the marker interval of RM6024 and RM1237 for grain length with Phenotypic Variance (PVE) of 3.7% by IM and a QTL, *qGB5.1* for grain breadth with PVE of 3.58% by CIM and 4.51 % by IM and a QTL *qGLB5.1* for grain length-breadth ratio with PVE of 11.8 % by IM in the marker interval of RM1237 and RM18582. In the present study, the QTL cluster region was narrowed down from 26.5cM to 15.6cM. These stable QTLs also facilitate development of Near-isogenic lines and advanced breeding lines.

Basmati rice is a unique varietal group that has gained wider acceptance as a speciality rice all over the world. Among the traits that determine the quality of Basmati rice, grain size is one of the important character not only from consumer's angle but more so from traders' and millers' angle. Grain size is characterized by grain length, grain breadth and grain length-breadth ratio. The preference for grain size varies with consumer. For instance, long and slender grain of *indica* rice is preferred by majority of consumers in India, China, Thailand, Pakistan and also in USA, while short grain of *japonica* rice are preferred in Japan and Korea (Unnevehr *et al*., 1992 and Juliano and Villareal, 1993). In India, consumer preference again varies with the region. Long slender grains are preferred in the north, while medium slender and short, bold grains are preferred in the south and east. Therefore, breeding for appropriate grain shape need to be considered in the context of market preference. Thus, in depth understanding of the genetic and molecular bases of grain size is warranted for directed improvement of rice keeping in view yield enhancement and quality enhancement and quality demand of domestic and export market.

Many independent studies have reported several QTLs for grain size characters in both sub-species of rice *viz*., *indica* and *japonica*. Major QTLs on the same regions of chromosome 3 and 5 for grain appearance traits in Basmati have been identified (Vemireddy, 2008). Hence, keeping this foregoing in view, it is proposed to confirm and dissect the already identified major QTLs for grain size on chromosomes 5 employing molecular marker analysis.

MATERIAL AND METHODS

Development of the mapping population:

Mapping population of 155 recombinant inbred lines (RILs) at F_6 stage developed from the cross of Basmati 370 and Jaya by employing single seed descent method (SSD) and made available from the study of Vemireddy (2008), were raised in college farm, Rajendranagar during *kharif* 2010-2011 in two replications in randomized block design (RBD). Four plants in the middle of each of these lines were tagged for recording phenotypic data.

Phenotyping for grain size:

The length and breadth of the grains was measured for a minimum of 10 fully filled rice grains of 4 plants from each line using seed/grain analyser and grain length-breadth ratio (LB ratio) was calculated dividing grain length by grain breadth.

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Genomic DNA extraction

Genomic DNA extraction was done using modified CTAB method (Vemireddy, 2008). The genomic DNA of parental lines and the mapping population were subjected to PCR amplification as per the procedure described by Chen *et al.* (1997).

Poymerase chain reaction

In the present study, the microsatellite markers present in the region harboring grain size QTL already identified by Vemireddy (2008) between the markers RM289 and RM18600 on chromosome 5 were selected for marker analysis using CHARM v 1.0 (Community Helping Advance Rice Markers) software (Table 2).

The PCR programme was set with initial denaturation at 94°C for 5 min, denaturation for 45 seconds, primer annealing at 55 to 60°C, extension at 72°C for 45 seconds. The steps 2, 3 and 4 were repeated for 35 times and final extension at 72°C for 10 minutes. Fifty three markers specific to chromosome 5 were used for polymorphism study in parents.

Linkage map construction and QTL detection: The phenotypic data obtained for the grain size traits and the genotypic data of all the 23 polymorphic markers were used for constructing linkage map. Linkage map was constructed using the MAPMAKER v 3.0 (Lincoln *et al.,* 1993) following Kosambi mapping function with LOD (Logarithm of odds ratio) score of 3.0 and a recombination fraction of 0.4. QTLs were detected by interval mapping (IM) (Lander and Botstein, 1989) and composite interval mapping (CIM) procedures of Windows QTL Cartographer v 2.5 software (Wang *et al.,* 2006). Map distance between the markers was presented in centimorgan (cM). The phenotypic variance (PVE) explained by each QTL and the additive effects were estimated and nomenclature of QTL was done as per McCouch *et al*. (1997).

RESULTS AND DISCUSSION

Phenotypic Trait Measurements, Frequency Distribution and Trait correlations: The parents used for mapping, Basmati 370 and Jaya differed significantly with respect to all the three traits *viz.,* grain length, grain breadth and Length Breadth (LB) ratio. The mean of the RIL population (F_6) was intermediate to the parents for grain length, grain breadth and LB ratio. All the three grain size related traits showed transgressive segregants (TS) ranging from 12.25 to 45.8% (Table 1) in both the directions except LB ratio which showed only towards higher parent Basmati 370.

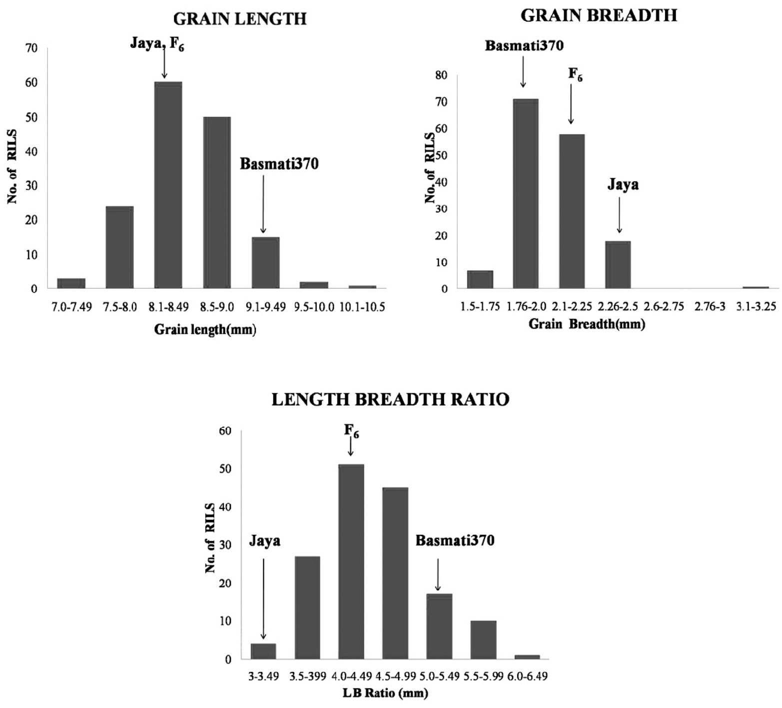

Fig. 1. Phenotypic distribution of grain size traits in RIL population

The transgressive segregants pattern of the RILs suggests that neither of the parents carry all positive or all negative alleles. Such transgressive segregation is possibly due to accumulation of complementary alleles from both the parents at multiple loci (Tanksley, 1998) and unmasking of recessive deleterious alleles due to inbreeding (Rick and Smith, 1953). Transgressive segregants were also obtained earlier by Amarawati *et al.* (2008) for grain length, grain breadth and LB ratio in their study using 209 RILs from the cross of a Basmati quality parent, Pusa 1121 and non-Basmati parent, Pusa1342.

All the three traits i.e., grain length, grain breadth and LB ratio exhibited normal distribution in the RIL population indicating quantitative inheritance of these traits (Figure 1). Correlation analysis among the grain size characters studied in RILs revealed a highly significant negative association of LB ratio with grain breadth and significant positive correlation with grain length (Table 2).

Correlation analysis among the grain size characters revealed negative association of LB ratio with grain breadth and positive correlation with grain length suggesting that as grain length increases, grain breadth decreases. These results are in agreement with the correlation coefficients of the grain size related traits obtained by Vemireddy (2008) from the data collected in F_2 progeny of the same cross. Amarawati *et al.* (2008) also reported the same association among the above mentioned traits.

Parental polymorphism study: Parental polymorphism survey between Basmati 370 and Jaya was conducted using 52 SSR and 1 indel markers specific to chromosome 5 of which, 23 markers showed polymorphism (43.30%), 21 were monomorphic (39.60%) and 9 were not amplified (16.98%) (Table 3) and the segregation pattern of RM18600 in RIL population is shown in Figure 2.

High parental polymorphism (43.30%) observed in the present study gives further evidence to the divergence and distinctness of Basmati rice from the other *indica* and *japonica* rice groups as revealed by an earlier study conducted by Nagaraju *et al.* (2002). The polymorphism (%) detected in the present study is higher than that reported by Amarawati *et al*. (2008) (28.9%) and lower than that reported by Govindaraj *et al*. (2005) (63.95%). The former had used evolved Basmati *i.e.,* Pusa 1121 as one of the parents and the later used a traditional Basmati *i.e*., Basmati 370. The RILs were genotyped for these 23 marker loci and the analysis showed that there was still some residual heterozygosity. The RILs developed by Amarawathi *et al.* (2008) from a cross between Pusa 1121 and Pusa 1342 also showed that there was still some residual heterozygosity in the RILs, probably due to insufficient number of self-pollination cycles at the F_6 generation.

Linkage Map Construction and Mapping of QTLs associated with Grain Size traits: The linkage map (LOD> 3.0) employing 23 polymorphic markers was constructed using Mapmaker version 3. Only one QTL *qGL5.1* was identified for grain length by IM in the marker interval of RM6024 and RM1237 (Table 4). It explained phenotypic variance (PVE) of 3.7% with an increasing effect allele coming from Basmati 370 and a single QTL designated as *qGB5.1* was detected for grain breadth in the marker interval of RM1237-RM18582 (Figure 3) with PVE of 3.58% by CIM (Table 5.) and 4.51% by IM (Table 4). The increased allele effect came from the parent Jaya, besides a single QTL *qLB5.1* in the marker interval of RM1237 and RM18582 was identified with PVE of 11.8% by IM (Table 4).

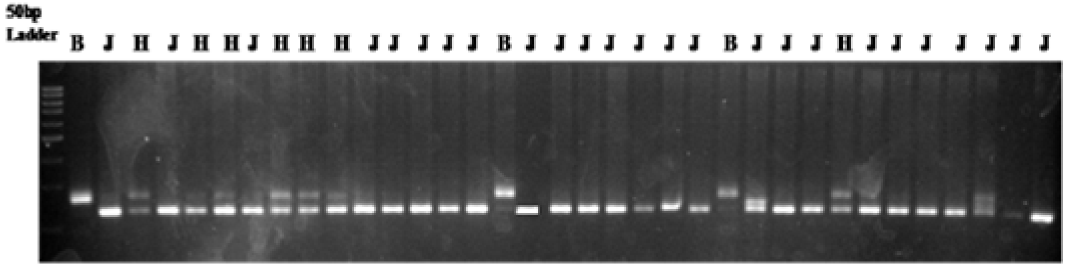

Figure 2. Seggregation pattern of RM18600 locus in RIL population

In F_2 population of the same cross, a QTL cluster was identified in the marker interval of RM289 and RM18600 on chromosome 5 by Vemireddy (2008) for grain size traits *viz.*, grain length, grain breadth and grain length-breadth ratio. The genetic distance of the flanking markers harboring QTL cluster in the previous study conducted by Vemireddy (2008) was 26.5 cM. In rice the average physical distance per genetic distance is approximately 250 kb cM^{-1} (Chen *et al.,* 2002). However, this distance is too long to be used in marker-assisted improvement of grain traits and also to pinpoint the underlying gene(s). Hence, in the present study an attempt has been made to fine tune this region. To this end, the F_2 population in which a QTL cluster was identified is advanced to F_6 generation allowing more meiotic events. All 155 recombinant inbred lines (RILs) were developed in F_6 generation and phenotyping for grain size traits and genotyping with additional microsatellite markers and indels inside and near the marker interval of RM289 and RM18600 was carried out. The phenotypic data and genotypic data was subjected to MAPMAKER V 3.0 and QTL Cartographer 2.5 to identify and narrow down the QTL cluster for the traits. In the present study it was made possible to narrow down the QTL cluster region from 26.5 cM to 15.7 cM (Figure 3). The physical distance also has come down from 11,128 kb to 685 kb. Comparision of rice genome database revealed that LOC_OS05g31920 (zinc ion binding protein), LOC_OS05g31930 (retrotransposon protein, putative, unclassified), LOC_OS05g31940 (retrotransposon protein, putative, unclassified), LOC_OS05g31950 (retrotransposon protein, putative, Ty3-gypsy subclass), LOC_OS05g31959 (hypothetical protein) and LOC_OS05g31970 (expressed protein) genes are present at this region. Interestingly, two predicted genes closer to this region *viz*., AP2 transcription factor (Ohto *et al.,* 2005 and Jofuku *et al.,* 2005) and RING E3 ligase (Song *et al.,* 2007) have been reported to be involved in controlling the seed size and weight. However, in the present study, one microsatellite marker *i.e*., RM18582 showed close association with the grain size QTLs. This marker has potential to be used in marker-assisted improvement of the grain size in Basmati rice after validation.

QTLs, which are consistently detected over a range of environments are considered to be "stable QTLs" and are preferred targets in crop improvement. Though the present study was carried out in single environment, together with the results of F_2 population of the same cross, it could be concluded that these three QTLs associated with grain size traits of Basmati could be considered as stable QTLs. According to Wan *et al.* (2005), QTLs with major effects are more likely to behave as stable QTLs across multiple environments. These QTLs, apart from their suitability in improvement of the traits concerned, can also serve as potential candidates for fine mapping. These stable QTLs also facilitate development of Near isogenic lines and advanced breeding lines.

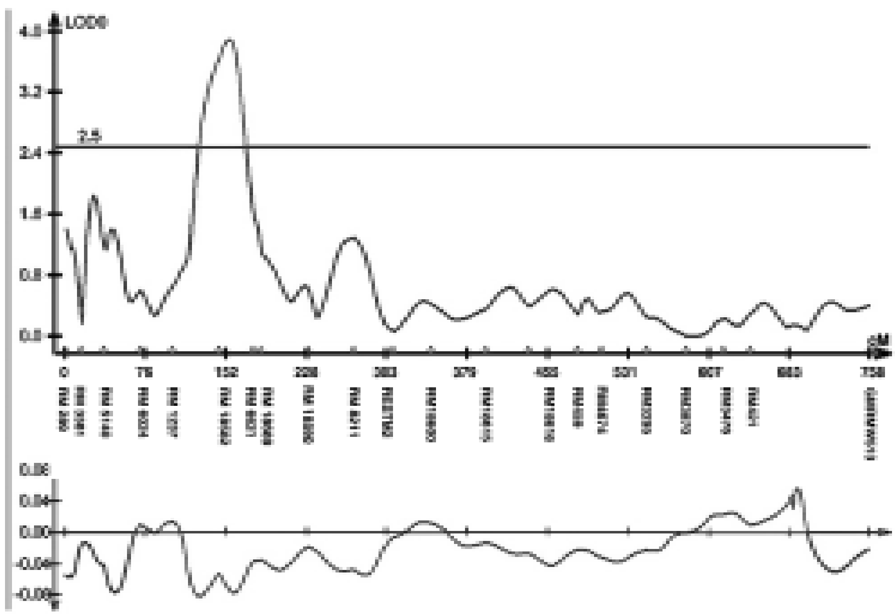

Figure 3. QTL for grain breadth

Table 1. Test of significance among parents, F_1 and RILs for grain size traits

S. No.	TRAIT	CODE	BASMATI 370(B)	JAYA(J)	F6	B/J	F6/B	J/F6	TS(%)
1.	Grain Length	GL	9.39$\pm$0.27	8.38$\pm$0.37	8.44$\pm$0.48	,,	,,	,,	45.8
2.	Grain Breadth	GB	1.87$\pm$0.05	2.73$\pm$0.11	2.02$\pm$0.194	,,	,,	,,	21.93
3.	LB Ratio	LBR	5.15$\pm$0.17	3.12$\pm$0.18	4.490$\pm$0.128	,,	,,	,,	12.25

Table 2. Correlation coefficients among grain size traits in RIL population

	GL	GB	LBR
GL	1.000	-	-
GB	-0.311	1.000	-
LBR	0.627*	-0.79 **	1.000

Table 3. Parental polymorphism study

Microsatellite markers	P/M/NA	No. of Markers
RM289, RM3381, RM5140, RM1237, RM6024, RM459, RM4674, RM3295, RM3870, RM3476, RM421, RM18615, RM18616, RM18582, RM18589, GMRMw513, RESTM2, RM18590, RM6621, RM 8211, RM18600, RM430, RM18614	P	23
RM18601, RM18612, RM18613, RM7568, RM18586, RM18596, RM5948, RM3969, RM2676, RM6645, RM3437, RM3838, RM598, RM5454, RM7363, RM3695, RM18587, RM18599, RM18602, RM18606, RM18607	M	21
RM18608, RM18584, RM18591, RM8039, RM6082, RM6551, RM4554, RM4959, RM6028	NA	9

P-polymorphic M-monomorphic NA-Not Amplified

Table 4. QTLs for grain size detected by Interval Mapping in the RIL population derived from a cross between Basmati 370 and Jaya

S.No	Trait	QTL	Chr	Marker interval	LOD	Additive	Dominance	PVE
1.	Grain length	*qGL 5.1*	5	RM6024-RM1237	2.67	0.047	0.53	3.7
2.	Grain breadth	*qGB 5.1*	5	RM1237-18582	3.84	-0.06	-0.09	4.51
3.	LB ratio	*qGLB 5.1*	5	RM1237-18582	5.43	0.17	0.69	11.8

Table 5. QTLs for grain size detected by Composite Interval Mapping in the RIL population derived from a cross between Basmati 370 and Jaya

S.No	Trait	QTL	Chr	Marker interval	LOD	Additive	Dominance	PVE
1.	Grain breadth	*qGB 5.1*	5	RM1237-18582	3.8	-0.05	-0.095	3.58

Further, several QTLs, each with different environment specificity, can be introgressed into a single genotype to develop phenotypes stable over a range of environments. In fact, in conventional plant breeding, selections are made in target environment and testing is done in multiple diverse environments. This exercise is cumbersome and time consuming. However, use of stable QTLs based selection can accelerate the pace of selection process in rice breeding programme.

From this study, it is obvious that the QTL controlling the grain size in Basmati rice is different from the major effect QTL identified in *indica* and *japonica* sub species of rice by previous workers. Hence, further investigation is warranted to dissect this region by developing large population of either F_2 or Near Isogenic Lines (NILs) and further confirmation by complementation tests and gene expression analyses.

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ESTIMATION OF HETEROSIS FOR GRAIN YIELD, ITS COMPONENTS AND GRAIN QUALITY TRAITS IN HYBRID RICE (*Oryza sativa* L.)

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ABSTRACT

The present investigation was carried out to study the magnitude of heterosis in yield components and grain quality traits of 27 rice hybrids developed by crossing three male sterile lines with seven restorers in line x tester design. The hybrids IR-80555A x RNR-17462 and IR-80555A x RNR-15028 showed desirable negative heterobeltiosis and standard heterosis for days to 50% flowering. The hybrids, IR-80555A x RNR-2458, IR-80555A x RNR-17462 and IR-79156A x RNR-2458 exhibited highly significant negative standard heterosis for plant height. Twenty hybrids were found to be significantly superior over the check for number of filled grains per panicle. The hybrids IR-80555A x RNR-15028 (33.35%), IR-68897A x RNR-2781 (26.13%) and IR-68897A x RNR-17462 (25.87%) showed highest significant positive heterosis over standard check for grain yield per plant. For the trait head rice recovery, 21 hybrids were found to be superior over the check within the range of 8.67 to 23.04 per cent. Highest positive standard heterosis was recorded by the hybrid IR-79156A x WGL-3962 (23.77%) for kernel length. The range of heterobeltiosis varied from -26.54 to 31.53 per cent for kernel L/B ratio. The hybrids, IR-79156A x RNR-15038 (25.40%) IR-68897A x RNR-15038 (24.33%) were found to be good for kernel length after cooking which expressed highest positive significant standard heterosis. The hybrids IR-68897A x RNR-17462, IR-68897A x WGL-3962, IR-80555A x RNR-2781 and IR-79156A x RNR-15038 were found to be good for yield contributing traits such as productive tillers per plant, number of filled grains per panicle, spikelet fertility (%), grain yield per plant, kernel length after cooking and kernel elongation ratio. The hybrid IR-79156A x RNR-15038, showed superiority for both yield components and quality traits.

Rice (*Oryza sativa* L.) is one of the most important food crops, feeding more than half of the world's population (Khush, 1997). In order to keep pace with the growing population, the estimated rice requirement in India by 2025 is about 130 m t. Plateauing trend in the yield of HYV's, declining and degrading natural resources and acute shortage of labour make the task of increasing rice production quite challenging. The current situation necessitates looking for some innovative technologies to boost up rice production in the country. Hybrid rice is one of the practically feasible and readily acceptable genetic options available with the yield advantage of 20% over the conventional high yielding varieties (Virmani and Kumar, 2004). Tiwari *et al.* (2011) studied the extent of heterosis in rice hybrids and reported the range of standard heterosis for grain yield from 10.48% to 71.56%. The challenge of quality improvement also needs to be addressed by evolving cultivars that combines high yield potential with quality attributes. In view of the above the present study was, undertaken to estimate the magnitude and direction of heterosis for grain yield and quality traits in hybrid rice.

MATERIAL AND METHODS

The material for the present investigation comprised of three lines, nine testers and their corresponding 27 hybrids obtained by Line x Tester mating design during *rabi* 2013-14. The hybrids KRH-2 and DRRH-3 were used as standard checks for quantitative and grain quality traits. The experiment was conducted in randomized block design with three replications at Rice Research Centre, PJTSAU, Rajendranagar, Hyderabad during *Kharif*, 2014. Thirty days old seedlings were transplanted with single seedling per hill in two rows of 3 m length with spacing of 20 x 15 cm and recommended agronomical practices and plant protection measures were followed. Ten random plants were selected from each entry in each replication to record observations on seven characters *viz*., days to 50 % flowering, plant height (cm), number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight (g), spikelet fertility (%) and grain yield per plant (g). Data was also collected for grain quality traits such as hulling (%), milling (%), head rice recovery (%), kernel length (mm), kernel breadth (mm), kernel L/B ratio, kernel length after cooking (mm) and kernel elongation ratio.

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Grain quality traits were estimated as per the procedure given by DRR, 2006. Mean data was utilized to estimate the heterosis (Liang *et al*., 1972) as the superiority of F_1 over better parent (heterobeltiosis) and standard check (standard heterosis).

RESULTS AND DISCUSSION

The analysis of variance revealed the presence of significant differences among the genotypes studied. The results indicated that many hybrids exhibited significant heterosis in desirable direction for different component traits. Out of 27 hybrids studied, 20 hybrids exhibited negative significant heterosis over better parent while only six hybrids recorded significant standard heterosis in desirable direction for days to 50% flowering. Negative heterosis for days to 50% flowering was also reported by Hariramakrishnan *et al*. (2009) and Srikrishna Latha *et al*. (2013). Ten hybrids exhibited heterobeltiosis in desirable direction for plant height. The hybrids, IR-80555A x RNR-2458, IR-80555A x RNR-17462 and IR-79156A x RNR-2458 recorded highly significant negative standard heterosis for plant height. Only two hybrids IR-68897A x RNR-17462 and IR-68897A x WGL-3962 showed significant positive heterobeltiosis for productive tillers per plant while none of the hybrids had positive significant standard heterosis. Among 27 hybrids studied, 14 hybrids expressed superiority over better parent and 23 hybrids over standard check (KRH-2) for number of filled grains per panicle. The hybrids, IR-80555A x RNR-2458 (68.16 %), IR-79156A x RNR-15351 (65.03%), IR-79156A x RNR-15028 (64.02%), IR-79156A x RNR-15038 (63.43%) and IR-80555A x RNR-2781 (60.42%) exhibited highly significant standard heterosis for number of filled grains per panicle. Only one hybrid (IR-80555A x RNR-2781) showed superior performance over the better parent for spikelet fertility per cent. The hybrid, IR-68897A x RNR-15398 (7.58%) found to possess highest positive standard heterosis for spikelet fertility percentage followed by IR-80555A x RNR-2781 (7.44%) and IR-68897A x RNR-2781 (7.08%). For 1000 grain weight only one hybrid IR-80555A x RNR-2781 (12.62%) exhibited significant positive standard heterosis. Sixteen hybrids were found to be significantly superior over better parent for grain yield per plant while nine hybrids were found to be superior over the standard check KRH-2. The hybrids, IR-80555A x RNR-15028 (33.35%), IR-68897A x RNR-2781 (26.13%) and IR-68897A x RNR-17462 (25.87%) exhibited highly significant positive heterosis over standard check for grain yield.

The magnitude and direction of heterosis over better parent varied from -5.39 (IR-80555A x RNR-15351) to 4.19 per cent (IR-80555A x RNR-17462) for hulling percentage (Table 2). Seven crosses showed significant positive standard heterosis over the check DRRH-3. Shivani *et al.* (2009) and Mahalingam and Nadarajan (2010) also reported positive standard heterosis for hulling percentage. For head rice recovery, only one hybrid (IR-68897A x RNR-15351) exhibited superiority over better parent. As many as 21 hybrids recorded significant positive heterosis over the check within a range of 8.67 to 23.04 per cent. Singh and Lal (2005) and Rukmini *et al*. (2014) also reported heterosis for head rice recovery at varying levels depending on parents involved. Highest positive standard heterosis was recorded by the hybrid IR-79156A x WGL-3962 (23.77 %) for kernel length. Heterosis in negative direction is highly desirable for kernel breadth in rice to develop varieties with fine grain quality. The hybrid IR-68897A x RNR-15028 showed highest significant negative heterobeltiosis (-28.54%) and standard heterosis (-23.39 %) for kernel breadth. The range of heterobeltiosis varied from -26.54 to 31.53 per cent for kernel L/B ratio. Similar results were obtained by Krishnaveni *et al.* (2005) and Kumar Babu *et al.* (2010) for kernel L/B ratio. The hybrids IR-79156A x RNR-15038 (25.40 %) and IR-68897A x RNR-15038 (24.33 %) recorded desirable standard heterosis for kernel length after cooking. Out of 27 hybrids evaluated only one hybrid IR-79156A x RNR-15038 (10.27%) found to have positive significant standard heterosis for kernel elongation ratio. Krishnaveni *et al.* (2005) and Roy *et al.* (2009) also reported manifestation of heterosis for kernel length after cooking and kernel elongation ratio.

It could be concluded from the study that the hybrids IR-68897A x RNR-17462, IR-68897A x WGL-3962, IR-80555A x RNR-2781and IR-79156A x RNR-15038 were found to be good for some of the yield contributing traits such as productive tillers per plant, number of filled grains per panicle, spikelet fertility (%), grain yield per plant, kernel length after cooking and kernel elongation ratio. Hence, these hybrids can be further tested and utilized for development of high yielding hybrids combined with grain quality.

Table 1. Estimates of heterosis for grain yield and its components in rice hybrids

Crosses	Days to 50 % flowering		Plant height (cm)		No. of productive tillers / plant		No. of filled grains / panicle		Spikelet fertility (%)		1000 grain weight (g)		Grain yield / plant (g)	
	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH
IR-79156 A x RNR-15351	-1.94	0.03	-4.03	-3.73	-42.42 **	-35.26 **	13.62 **	65.03 **	-4.18	-0.31	-22.37 **	-36.65 **	-12.52 *	-27.11 **
IR-79156 A x WGL-3962	-6.15 **	0.66	-2.84	0.89	-28.02 **	-19.08 *	36.94 **	25.25 **	0.49	4.54 *	-9.41 **	-6.15 *	19.70 **	-15.90 **
IR-79156 A x RNR-15398	-6.34 **	2.31	2.52	7.28 *	-38.69 **	-31.07 **	-5.73	29.00 **	-7.97 **	-4.26	-6.42 *	-23.63 **	-25.53 **	-38.77 **
IR-79156 A x RNR-15028	-6.84 **	-5.61 *	-4.75	-4.45	-26.86 **	-17.77 *	5.55	64.02 **	-0.30	6.28 **	3.48	-15.55 **	-8.76 *	1.81
IR-79156 A x RNR-15038	-2.22	1.98	-20.63**	-13.81 **	-9.15	2.14	-1.24	63.43 **	1.45	5.57 *	8.87 **	-11.15 **	12.01 *	15.91 **
IR-79156 A x RNR-2458	-4.28	3.30	-29.76**	-23.61 **	-40.87 **	-33.53 **	-6.58	10.41	-8.25 **	-4.55 *	7.68 *	-12.12 **	-15.59 *	-33.70 **
IR-79156 A x RNR-2456	-6.44 **	0.66	-2.64	-2.34	-11.05	0.04	60.69 **	55.55 **	-8.38 **	-4.69 *	-1.50	-19.49 **	51.09 **	6.15
IR-79156 A x RNR-17462	-11.30 **	3.63	0.83	3.99	-24.50 **	-15.12	39.95 **	39.48 **	-11.41 **	-7.83 **	12.37 **	-8.29 **	19.22 **	-16.24 **
IR-79156 A x RNR-2781	-10.92 **	2.31	-5.67*	11.18 **	-9.36	1.91	10.54 *	54.48 **	-1.53	2.44	16.41 **	-5.00 *	42.11 **	20.10 **
IR-80555 A x RNR-15351	-8.74 **	-6.93 **	-10.29**	-13.79 **	8.03	6.94	2.94	49.50 **	-5.29 *	-2.77	-1.08	-16.12 **	19.75 **	-0.22
IR-80555 A x WGL-3962	-13.85 **	-7.59 **	-0.44	3.39	5.41	-2.51	67.01 **	52.75 **	-2.26	0.34	-7.69 **	-4.37	42.51 **	-0.23
IR-80555 A x RNR-15398	-5.14 *	3.63	-12.22**	-8.14 **	13.01	8.47	-33.97 **	-9.64	-5.86 **	-3.36	-6.65 *	-20.84 **	-47.70 **	-57.00 **
IR-80555 A x RNR-15028	-8.11 **	-10.23 **	1.46	-12.14 **	2.06	11.5	0.79	56.62 **	-0.01	6.59 **	12.14 **	-4.91	19.52 **	33.35 **
IR-80555 A x RNR-15038	-2.85	1.32	-10.97**	-3.32	8.09	11.21	-6.81	54.22 **	0.23	4.30	-6.03 *	-20.31 **	5.81	9.49 *
IR-80555 A x RNR-2458	-6.12 **	1.32	-28.30**	-22.03 **	6.87	-1.16	42.28 **	68.16 **	-7.38 **	-4.91 *	-37.71 **	-47.18 **	-3.65	-24.32 **
IR-80555 A x RNR-2456	-8.90 **	-1.98	-0.67	-6.66 *	-3.13	-10.4	19.32 **	15.50 *	-4.03	-1.48	-5.66	-20.00 **	20.37 **	-17.59 **
IR-80555 A x RNR-17462	-16.38 **	-2.31	-24.63**	-22.27 **	-4.06	-11.27	16.31 *	15.92 *	-1.70	0.92	9.14 **	-7.45 **	22.36 **	-16.54 **
IR-80555 A x RNR-2781	-12.07 **	0.99	-2.96	14.37 **	7.76	6.36	14.79 **	60.42 **	4.65 *	7.44 **	32.81 **	12.62 **	47.65 **	24.78 **
IR-68897 A x RNR-15351	-4.21	-2.31	1.12	-2.83	-9.49	-10.40	-2.36	41.81 **	-1.75	2.38	-1.91	-9.96 **	18.33 **	-1.40
IR-68897 A x WGL-3962	-5.85 *	0.99	-2.19	1.58	21.82 *	12.14	74.12 **	59.25 **	-4.37 *	-0.35	-13.95 **	-10.85 **	65.14 **	15.61 **
IR-68897 A x RNR-15398	-7.85 **	0.66	-0.54	4.08	-10.87	-14.45	4.05	42.39 **	3.25	7.58 **	-0.37	-8.55 **	15.13 *	-5.34
IR-68897 A x RNR-15028	-4.81	-8.58 **	4.82	-8.12 **	-30.03 **	-23.55 **	-40.12 **	-6.95	-6.88 **	-0.73	-0.45	-8.62 **	-39.60 **	-32.61 **
IR-68897 A x RNR-15038	-3.48	0.66	-9.46**	-1.68	-1.57	1.27	-13.40 **	43.31 **	1.03	5.27 *	0.09	-8.12 **	-31.96 **	-29.60 **
IR-68897 A x RNR-2458	-8.87 **	-1.65	-3.11	5.37	-2.85	-16.18 *	-35.67 **	-23.97 **	-12.88 **	-9.22 **	-3.98	-11.86 **	-18.76 **	-36.19 **
IR-68897 A x RNR-2456	-11.96 **	-5.28 *	18.54**	11.39 **	-1.22	-22.92 **	36.30 **	31.94 **	-2.89	1.19	-11.06 **	-18.36 **	-0.36	-31.78 **
IR-68897 A x RNR-17462	-12.15 **	2.64	2.00	5.19	32.22 **	3.18	58.50 **	57.96 **	-8.32 **	-4.47 *	-6.73 *	-14.39 **	84.53 **	25.87 **
IR-68897 A x RNR-2781	-12.07 **	0.99	-16.34**	-1.40	8.14	6.73	12.13 **	56.71 **	2.76	7.08 **	9.27 **	0.30	49.26 **	26.13 **

*, ** = Significant at 5 % and 1 % level, respectively   HB- Heterobeltiosis   SH-Standard heterosis

Table 2. Estimates of heterosis for grain quality traits in rice hybrids

Crosses	Hulling (%)		Head Rice Recovery (%)		Kernel Length (mm)		Kernel Breadth (mm)		Kernel L/B ratio		Kernel Length After Cooking (mm)		Kernel Elongation Ratio	
	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH
IR-79156 A x RNR-15351	-1.61	3.85 *	5.87	16.00 **	1.41	17.71 **	-8.66 **	-15.94 **	4.47	40.07 **	-14.56 **	-5.68	-16.73 **	-19.85 **
IR-79156 A x WGL-3962	-3.47	4.83 *	-6.31	17.59 **	6.63 **	23.77 **	-21.80 **	-15.17 **	8.80 **	45.88 **	5.83 *	16.83 **	-0.72	-5.57
IR-79156 A x RNR-15398	-5.27 **	-0.01	-7.46 *	6.69	-8.21 **	6.54 *	20.63 **	8.23 **	-26.54 **	-1.50	-12.14 **	-3.00	-4.17	-8.85 *
IR-79156 A x RNR-15028	-2.35	3.07	1.59	11.31 **	5.22 *	22.14 **	-23.02 **	-17.48 **	10.34 **	47.94 **	1.94	12.54 **	-10.28 *	-7.58
IR-79156 A x RNR-15038	-2.95	2.44	-5.91	8.67 *	-1.99	13.76 **	-11.99 **	-16.97 **	2.23	37.08 **	13.59 **	25.40 **	8.38 *	10.27 *
IR-79156 A x RNR-2458	-4.76 *	0.52	-6.95 *	12.15 **	-11.69 **	2.50	2.48	-4.37	-19.97 **	7.30 *	-7.77 **	1.82	4.45	-0.65
IR-79156 A x RNR-2456	-3.68 *	1.66	0.04	17.83 **	-8.04 **	6.74 *	15.93 **	1.03	-21.23 **	5.62	-6.80 *	2.89	1.30	-3.64
IR-79156 A x RNR-17462	-2.50	2.90	3.66	16.76 **	-12.19 **	1.92	-21.67 **	-22.88 **	-1.40	32.21 **	-2.91	7.18 *	10.69 *	5.28
IR-79156 A x RNR-2781	-2.98	2.40	1.71	11.44 **	-0.83	15.11 **	3.86	10.54 **	-22.35 **	4.12	-2.09	8.09 *	-8.57 *	-6.12
IR-80555 A x RNR-15351	-5.39 **	-1.46	-9.46 *	-3.61	-3.14	3.95	-9.79 **	-12.34 **	7.29 *	18.54 **	0.00	-2.47	-2.36	-6.02
IR-80555 A x WGL-3962	-2.80	5.56 **	-7.21 *	16.45 **	1.08	17.13 **	-24.17 **	-17.74 **	28.98 **	42.51 **	9.36 **	18.38 **	8.15	1.07
IR-80555 A x RNR-15398	-1.27	0.40	-12.60 **	0.77	0.09	7.41 *	-20.37 **	-22.62 **	25.76 **	38.95 **	4.95	2.36	0.41	-4.60
IR-80555 A x RNR-15028	1.44	3.51	6.50	16.32 **	1.97	9.43 **	11.03 **	19.02 **	-16.78 **	-8.05 *	2.20	-0.32	-11.57 **	-8.91 *
IR-80555 A x RNR-15038	-1.99	2.97	-1.57	13.67 **	9.96 **	18.00 **	-12.96 **	-15.42 **	26.27 **	39.51 **	-3.30	-5.68	-21.42 **	-20.05 **
IR-80555 A x RNR-2458	-4.51 *	-1.37	-6.31	12.93 **	-0.36	6.93 *	11.64 **	8.48 **	-10.68 **	-1.31	5.16	2.57	5.61	-4.04
IR-80555 A x RNR-2456	-2.58	1.37	-5.14	11.73 **	8.88 **	16.84 **	-17.20 **	-19.54 **	31.53 **	45.32 **	9.78 **	7.07 *	0.88	-8.34
IR-80555 A x RNR-17462	4.19 *	6.66 **	5.21	18.50 **	0.27	7.60 **	-18.80 **	-20.05 **	21.86 **	34.64 **	-2.20	-4.61	-2.45	-11.36 **
IR-80555 A x RNR-2781	2.57	2.26	-1.06	7.96	3.68	11.26 **	16.67 **	24.16 **	-18.98 **	-10.49 **	7.29 *	10.40 **	-3.35	-0.76
IR-68897 A x RNR-15351	1.95	6.19 **	14.50 **	23.04 **	-6.73 **	8.08 **	-10.13 **	-13.37 **	3.74	24.72 **	-11.24 **	-1.39	-5.20	-8.76 *
IR-68897 A x WGL-3962	-3.33	4.99 *	-9.01 **	14.20 **	-2.82	12.61 **	-22.51 **	-15.94 **	11.37 **	33.90 **	-1.59	9.32 **	1.30	-2.91
IR-68897 A x RNR-15398	-0.83	0.84	-3.95	10.74 *	-5.81 *	9.14 **	12.80 **	8.74 **	-16.51 **	0.37	-17.99 **	-8.90 **	-12.84 **	-16.46 **
IR-68897 A x RNR-15028	-0.94	1.08	1.88	11.27 **	-10.96 **	3.18	-28.54 **	-23.39 **	12.15 **	34.83 **	-8.83 **	1.29	-4.68	-1.81
IR-68897 A x RNR-15038	-2.94	1.97	-6.57	7.90	2.74	19.06 **	-10.40 **	-13.62 **	14.80 **	38.01 **	11.92 **	24.33 **	2.67	4.45
IR-68897 A x RNR-2458	-0.67	2.60	-3.00	16.92 **	-12.46 **	1.44	-14.93 **	-17.99 **	2.96	23.78 **	-15.58 **	-6.22	-3.55	-7.55
IR-68897 A x RNR-2456	1.68	5.80 **	2.24	20.43 **	-5.73 *	9.24 **	15.47 **	11.31 **	-18.22 **	-1.69	6.13 *	17.90 **	12.63 **	7.95
IR-68897 A x RNR-17462	0.00	2.36	0.12	12.77 **	-4.65	10.49 **	-9.66 **	-11.05 **	3.58	24.53 **	-16.06 **	-6.75 *	-11.93 **	-15.59 **
IR-68897 A x RNR-2781	2.30	3.53	-0.74	8.31	-5.65 *	9.34 **	-23.43 **	-18.51 **	11.68 **	34.27 **	-7.38 *	2.89	-8.29 *	-5.83

*, ** = Significant at 5 % and 1 % level, respectively HB- Heterobeltiosis SH-Standard heterosis

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INFLUENCE OF PLANTING METHODS AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON YIELD ATTRIBUTES, YIELD AND ECONOMICS OF RICE

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ABSTRACT

A field experiment was conducted during *kharif* Season of 2010-11and 2011-12 at AICRP on Rice, Agricultural Research Institute (ARI), Rajendranagar, Hyderabad to evaluate different planting methods (SRI, Yangio - China, Kobota transplanter and farmers method) and integrated nutrient management (INM) practices *viz.,*100% RDF, (150 : 60 : 40 kg N, P_2O_5 & K_2O ha^{-1}), FYM, GLM @ 5 t ha^{-1}, bio-fertiliser (*Azospirillum* @ 2.5 kg ha^{-1}+ PSB @ 5 kg ha^{-1}) along with 100% RDF. The higher mean grain, straw yield and B:C ratio (average of two years) was recorded with machine (Kobota) transplanting (7.0, 16.02 t ha^{-1} & 2.20) followed by farmers method (manual) of planting (6.30, 13.32t ha^{-1} & 2.00) and was found on par to SRI method (5.8,11.40 t ha^{-1} & 1.60). The lowest mean grain, straw yield and B:C was obtained with Yangio-China transplanter (5.20, 8.42 t ha^{-1} & 1.30). Among the INM practices greater mean grain, straw yield and B:C ratio values were registered with application of 100% RDF + FYM @ 5 ha^{-1} (6.90, 15.60 ha^{-1} & 2.00) over other INM treatments. Application of GLM @ 5 ha^{-1} + RDF produced higher mean grain and straw yield (6.40 and 13.30 t ha^{-1}) and B:C ratio (1.80) followed by RDF + BF 7.5 kg ha^{-1}). Significant interaction effect was obtained in straw yield & B:C ratio (Pooled mean). Transplanting of rice with Kobota transplanter along with application of FYM @ 5 t ha^{-1} + RDF (M_3I_1) was found significant in recording more straw yield (19.67 t ha^{-1}) and B:C ratio (2.40) as compared to other treatment combinations followed by the combination of farmers method of planting along with RDF + FYM @ 5 t ha^{-1} (M_4I_1) (17.57 t ha^{-1} and 2.37).

Rice is the staple food crop in Asia including India. In India it is grown in an area of 44.41 m ha with a production of 104 m t and productivity of 2.2 t ha^{-1} (CMIE, 2011). In Andhra Pradesh, the area was 4.0 lakh ha and production was 12.8 lakh tonnes. Rice is mainly grown in canal command areas with assured irrigation facilities. Rice is traditionally transplanted but in recent years because of shortage of labour coupled with higher wages during the peak period of farm operations lead to delay in transplanting. This was aggravated by untimely release of water from canals and delayed monsoon showers. This lead to indenting alternate methods of rice cultivation without reduction in yield. Among them, transplanting using mechanical transplanter and SRI method of cultivation gained significance among farmers because of easy adoptability and on par yield with that of conventional transplanting method. Rice transplanters are available from different companies. Mechanization (both for planting and harvesting) in rice cultivation revolutioned the rice cultivation by decreasing cost of cultivation. In Andhra Pradesh, which is called as " rice bowl of India", rice growing has become burden on farmers as the cost of labour increased many fold with more or less same yield. On the other side, mechanical transplanting has its own disadvantages like special nursery, non uniformity in number of seedlings hill^{-1} and main field preparation. Introduction of high yielding varieties responsive to chemical nutrients brought a spectacular increase in use of chemical fertilizers in rice. Nutrient mining by high yielding varieties was usually more than that applied through chemical fertilizers. This type of nutrient mining over years led to impoverishment of soil fertility and decline in crop productivity (Nambiar, 1992). Integrated use of chemical fertilisers with manures and green manure crop is important for sustainable rice production. The increased prices of fertilizers also intensified the problem by increasing cost of inputs. Hence, the mechanical transplanters and INM practices were evaluated with an aim to reduce the cost of cultivation and to increase the productivity of rice.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* season of 2010-11 and 2011-12 at AICRP on Rice, Agricultural Research Institute, Rajendranagar,

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Hyderabad. The soil of the experimental field was sandy clay loam in texture with pH 7.7, organic carbon 0.67% and available N, P_2O_5 and K_2O as 245.6,38.5 and 301 kg ha^{-1}, respectively during first season (2010) and with pH 7.82, organic carbon 0.65 and available N, P_2O_5 and K_2O as 215.1,31.6 and 288.2 kg ha^{-1}, respectively during 2011. The total rainfall received during crop growth period during 2010 [1st July - 30th October (120 days)] was 485.9 mm in 31 rainy days and during 2011 (July -7 th November, 2011 (127)) the crop period was recorded 615.8 mm in 39 rainy days. Four planting methods *viz.,* two mechanical transplanters (Kobota and Yangio - China transplanters), farmers method of planting and SRI method were tested in main plots with four integrated nutrient management (INM) treatments as sub plots - I_1 -100% RDF + FYM @ 5 t ha^{-1}, I_2 -100% RDF + GLM @ 5 ha^{-1}, I_3 - 100% RDF + *Azospirillum* @ 2.5 kg ha^{-1}+PSB @ 5 kg ha^{-1} and I_4 - only 100% RDF (150 N, 60 P_2O_5, 40 K_2O Kg ha^{-1}) were evaluated in split plot design with three replications.

The plot size adopted was 11.5 m x 4.0 m. For Mechanical transplanting, pre-germinated seeds (soaked for 24 hrs.) in gunny bag were spread uniformly on mat type of nursery and 15 days old seedlings were used. Raised bed nursery was prepared for SRI and farmers method and 10 days old seedlings were used for SRI method and for farmer's method of planting, 25-30 days old seedlings were used. The spacing maintained for Kobota transplanter was 30 cm x 12 cm, Yangio - China transplanter was 22.5 cm x 14 cm (the intra row spacing was adjusted by controlling the length of pulling of machine), 25 cm x 25 cm in SRI method of planting (with marker) and Zig Zag planting in farmer's method. Rice variety "Satya" was used in the experiment. Organic manures i.e., FYM and green leaf manure (GLM) @ 5 t ha^{-1} were applied one week before transplanting, 1/3rd nitrogen, total phosphorus and 2/3rd potassium were applied basally at the time of transplanting. At maximum tillering stage 1/3rd N and remaining 1/3rd N and 1/3rd potassium were applied at panicle initiation stage. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The crop was sown on 1st July in both the years. Biofertilizers i.e., *Azospirillum* @ 2.5 kg ha^{-1} and PSB @ 5 kg ha^{-1} was applied 3 days after transplanting. In SRI method, cono weeder was operated 3-4 times for control of weeds and aeration but for remaining planting methods, pre-emergence application of butachlor @ 1.5 kg *ai* ha^{-1} was applied 2 days after transplanting followed by one hand weeding at 30 DAT for weed control. The yield attributes, grain and straw yield were recorded at the time of harvest. Economics was calculated based on the cost of prevailing market rates of inputs and yield of rice crop.

RESULTS AND DISCUSSION

The panicle number per meter square of rice was significantly influenced by planting methods and INM practices during both the years, except INM practices during 2011-12. Among the planting methods, transplanting with Kobota transplanter was found better with higher no. of panicles m^{-2} (498.9 and 566.2) over other treatments. However, manual transplanting in farmer's method was found on par to machine transplanting with Kobota with respect to panicle number m^{-2} during both the years. The increase in number of panicles m^{-2} with Kobota transplanter was mainly due to optimum plant population and plant geometry (30 cm x 12 cm) that resulted in even distribution of light, moisture and nutrients among rice plants leading to better growth and yield attributes. This was also reported by Anbumani *et al*., (2004) and Singh *et al*., 2009.

The effect of INM practices on panicles number m^{-2} was not significant during 2011-2012. During 2010-2011, application of FYM @ 5 t ha^{-1} + RDF recorded high panicle number m^{-2} (495.5) which was on par with GLM @ 5 t ha^{-1} + RDF (477.6) over other tratments. These findings are in collaboration with the findings of Barik *et al.,* (2006). The interaction was found insignificant during both the years.

Significantly highest number of grains per panicle were observed when the crop was transplanted with Kobota transplanter compared to other transplanting methods during both the years. However, it was on par with farmers method of planting during 2011-12. This may be due to more light interception because of wider spacing (30 x 12 cm), that resulted in more dry matter accumulation and partitioning into sink (panicles). Farmers method of transplanting was on par with SRI method during both the years and also with Yangio - China transplanter during 2010-11. Lower number of grains panicle^{-1} was reported with Yangio - China transplanter method. Among the INM practices, application of RDF + FYM @ 5t ha $^{-1}$ produced more number of grains panicle^{-1} during both the years over the other treatments. However, it was on par with RDF + GLM @ 5 t ha^{-1} during 2011-12. Nutrients available from decomposing manure to the rice crop during the reproductive stage were utilised for grain formation and grain filling leading to higher no. of grains per panicle. This was supported by Anup Dixit *et al*., (2007).

Grain yield of rice was significantly influenced by planting methods, integrated nutrient management (INM) practices and their interaction during both the years. Among different planting methods, transplanting with Kobota transplanter was found superior to all other crop establishment methods (6.50 & 7.50 t ha^{-1}). However, during 2011-12, farmer's method (6.91 t ha^{-1}) of planting was found on par to Kobota transplanting. Better vegetative growth, dry matter accumulation and effective partitioning to the panicles resulted in more number of panicles m^{-2} and grains panicle^{-1} in these treatments which has ultimately improved grain yield. The increase in grain yield in machine transplanting was in agreement with the results reported by Anoop Dixit *et al.,* 2007, Manjunatha *et al.,* 2009 and Venkateshwarlu *et al.,* 2011. Kobota transplanter method recorded yield increase of 11.1, 20.7 and 34.6 percent (on pooled mean) over farmers method, SRI and Yangio China transplanter, respectively. The Yangio-China transplanter being heavy machine compared to Kobota sank in the field resulting in uneven planting, higher depth of planting and in turn less number of tillers m^{-2}, less number of panicles m^{-2}, number of grains panicle^{-1} and inturn lower grain yield (4.61 t ha^{-1}). Among the integrated nutrient management practices, the higher grain yield (6.41, 7.42 and 6.9 t ha^{-1}) was obtained with RDF+FYM@ 5 t ha^{-1} which was significantly superior to all the other practices during both the years. However, during 2011-12 the grain yield recorded with GLM @ 5 t ha^{-1} + RDF (6.90 t ha^{-1}) was found on par with above treatment. The increase in yield (pooled mean) was 32.7, 23.1 and 9.6 percent with FYM, GLM and BF over only RDF treatment. The higher yield with integrated use of organic and inorganic fertilisers might be attributed to increased availability of major and minor nutrients by improving physical and chemical environment of the soils. The superiority of FYM in increasing the yield was supported by Barik *et al.,* 2006. The superiority of green leaf manuring was supported by Rajbir Garg *et al*., 2007 and Anchal Das *et al*., 2009. The superiority of biofertilizers was reported by Jagdish Kumar *et al.,* 2010. The interaction between planting methods and integrated nutrient management practices was significant during both the years (Table 1b and 1c). The Kobota transplanter method along with RDF + FYM @ 5 t ha^{-1} (M_3 I_1) produced significantly higher grain yield over other treatment combinations but was on par with same transplanter method along with RDF + GLM @ 5t ha^{-1} (M_3I_2) during 2010-11. During 2011 Kobota transplanter along with FYM @ 5 t ha^{-1} (M_3I_1) exhibited higher grain yield but on par with M_3I_2 (Kobota + RDF + GLM @ 5 t ha^{-1}), M_3I_4 (Kobota + RDF), M_4 I_1 (Farmers method + RDF + FYM @ 5t ha^{-1}), M_4I_2 (Farmers method+ RDF + GLM @ 5t ha^{-1}), M_4 I_3 (farmers method + RDF + BF @ 7.5 kg ha^{-1}) and M_1 I_1 (SRI method + RDF + FYM @ 5 t ha^{-1}). The better performance of crop in the above combinations was the outcome of enhanced growth measured in terms of plant height, hastened development, improved yield attributes and hence yield (Shekhar *et al*., 2009).

Straw yield of rice varied significantly due to planting methods and INM practices. The crop transplanted with Kobota transplanter has maintained comparably higher number of tillers hill^{-1} and accumulated greater biomass during both the years of study and hence their pooled mean. The increase in straw yield due to Kobota transplanting was to the tune of 20.3 % over manual transplanting. On the other side, Yangio-China transplanter method gave lowest straw yield compared to the other methods. Farmers method of planting recorded straw yield next to Kobota transplanter and was followed by SRI method of planting during both the years and hence pooled mean. Similar increase was reported by Anbumani *et al*., 2004 and Singh *et al*., 2009. The demonstrated effect of FYM along with RDF on grain yield has been repeated once again with straw yield as adequate stalk production is obligatory for effective photosynthesis and steady transport of nutrients and metabolites required for grain production. The straw yield registered in this treatment was found directly proportional to tiller formation and dry matter

Table 1. Yield attributes, grain, straw yield and economics of rice as influenced by planting methods and integrated nutrient management practices.

Treatment	Panicles m^{-2}		Grains $panicle^{-1}$		Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			B:C Ratio (Rs)		
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**Pooled**	**2010**	**2011**	**Pooled**	**2010**	**2011**	**Pooled**
Planting methods													
M_1 - SRI	450.3	528.2	319.9	323.8	5.30	6.30	5.80	10.38	12.37	11.40	1.40	1.80	1.60
M_2 - Yangio - China	412.1	513.6	302.5	308.2	4.61	5.82	5.20	07.51	09.36	08.42	1.00	1.53	1.30
M_3 - Kobota	498.9	566.2	348.7	359.1	6.50	7.50	7.00	14.89	17.12	16.02	2.00	2.40	2.20
M_4 - Farmer's method	481.9	546.5	321.5	339.9	5.58	6.91	6.30	11.87	14.75	13.32	1.70	2.30	2.00
SEm±	10.5	8.7	5.6	6.3	0.11	0.27	0.15	0.20	0.47	0.23	0.04	0.12	0.06
CD (P=0.05)	36.5	30.0	19.2	21.9	0.38	0.92	0.51	0.70	1.64	0.79	0.15	0.41	0.22
INM practices													
I_1 - RDF+FYM@ 5 t ha^{-1}	495.5	556.4	353.7	358.9	6.41	7.42	6.90	14.46	16.69	15.60	1.83	2.20	2.00
I_2 - RDF+GLM @ 5 t ha^{-1}	477.6	545.4	330.8	344.5	5.87	6.90	6.40	12.15	14.33	13.30	1.60	2.00	1.80
I_3 - RDF+BF Azospirillum @ 2.5 kg ha^{-1} +PSB @5 kg ha^{-1})	447.3	533.4	313.4	325.0	5.10	6.40	5.70	09.79	12.22	11.00	1.40	1.98	1.70
I_4 - RDF (150 N:60 P_2O_5 : 60 K_2O kg ha^{-1})	422.8	519.3	294.9	302.5	4.61	5.84	5.20	08.26	10.35	09.31	1.22	1.81	1.52
SEm±	9.9	9.9	5.2	9.0	0.10	0.19	0.13	0.23	0.33	0.20	0.04	0.07	0.05
CD (P=0.05)	21.7	NS	15.1	26.3	0.30	0.55	0.36	O.67	0.97	0.59	0.13	0.21	0.13
Interaction	NS	NS	NS	S	S	S	NS	S	S	S	S	S	S

Table 1a. Interaction effect on grains panicle^{-1} of rice as influenced by planting methods and INM practices during 2011-2012

Interaction	Grains panicle^{-1}				
	M_1 - SRI	M_2 - Yangio china	M_3 - Koboto	M_4 - Farmer's method	Mean
I_1 - RDF+FYM@ 5 t ha^{-1}	344.10	331.33	378.83	381.53	**358.94**
I_2 - RDF+GLM @ 5 t ha^{-1}	327.00	305.17	376.93	369.03	**344.53**
I_3 - RDF+BF @ 7.5 kg ha^{-1}	315.37	302.93	317.63	363.90	**324.96**
I_4 - RDF (150 N:60 P_2O_5 : 60 K_2O kg ha^{-1}	308.57	293.23	362.83	245.33	**302.49**
Mean	**323.75**	**308.17**	**359.06**	**339.95**	
	M x I	**I x M**			
S.Em ±		18.0	52.6		
CD (P=0.05)		16.9	18.8		

Table 1b. Interaction effect on grain yield t ha^{-1} of rice as influenced by planting methods and INM practices during 2010-2011

Interaction	Grain Yield				
	M_1 - SRI	M_2 - Yangio china	M_3 - Koboto	M_4 - Farmer's method	Mean
I_1 - RDF+FYM@ 5 t ha^{-1}	6.08	5.42	7.52	6.63	**6.41**
I_2 - RDF+GLM @ 5 t ha^{-1}	5.22	5.36	7.07	5.82	**5.87**
I_3 - RDF+BF @ 7.5 kg ha^{-1}	4.97	4.39	5.96	4.99	**5.08**
I_4 - RDF (150 N:60 P_2O_5 : 60 K_2O kg ha^{-1}	4.86	3.26	5.42	4.89	**4.61**
Mean	**5.28**	**4.61**	**6.50**	**5.58**	
	M x I	**I x M**			
S.Em ±		0.21	0.21		
CD (P=0.05)		0.60	0.65		

Table 1c. Interaction effect on grain yield t ha^{-1} of rice as influenced by planting methods and INM practices during 2011-2012

Interaction	Grain Yield				
	M_1 - SRI	M_2 - Yangio china	M_3 - Koboto	M_4 - Farmer's method	Mean
I_1 - RDF+FYM@ 5 t ha^{-1}	6.91	6.56	8.21	8.00	**6.41**
I_2 - RDF+GLM @ 5 t ha^{-1}	6.51	5.77	7.82	7.51	**5.87**
I_3 - RDF+BF @ 7.5 kg ha^{-1}	6.07	5.33	6.70	7.36	**5.08**
I_4 - RDF (150 N:60 P_2O_5 : 60 K_2O kg ha^{-1}	5.71	5.60	7.28	4.75	**4.61**
Mean	**7.50**	**5.82**	**6.30**	**6.91**	
	M x I	**I x M**			
S.Em ±		0.38	0.42		
CD (P=0.05)		1.10	1.32		

Table 1d. Straw yield (t ha^{-1}) of rice as influenced by planting methods and INM practices

Interaction	Straw yield (t ha^{-1}) Pooled				
	M_1 - SRI	M_2 - Yangio china	M_3 - Koboto	M_4 - Farmer's method	Mean
I_1 - RDF+FYM@ 5 t ha^{-1}	14.30	10.77	19.67	17.57	**15.57**
I_2 - RDF+GLM @ 5 t ha^{-1}	11.73	9.50	17.13	14.67	**13.25**
I_3 - RDF+BF @ 7.5 kg ha^{-1}	10.50	7.30	13.90	12.33	**11.00**
I_4 - RDF (150 N:60 P_2O_5 : 0 K_2O kg ha^{-1}	9.00	6.17	13.40	8.70	**9.31**
Mean	**11.38**	**8.42**	**16.02**	**13.32**	
	M x I	**I x M**			
S.Em ±		0.40	0.42		
CD (P=0.05)		1.17	1.28		

Table 1e. B:C Ratio of rice as influenced by planting methods and INM practices

Interaction	B : C Pooled				
	M_1 - SRI	M_2 - Yangio china	M_3 - Koboto	M_4 - Farmer's method	Mean
I_1 - RDF+FYM@ 5 t ha^{-1}	1.77	1.47	2.40	2.37	**2.00**
I_2 - RDF+GLM @ 5 t ha^{-1}	1.50	1.33	2.23	2.10	**1.80**
I_3 - RDF+BF @ 7.5 kg ha^{-1}	1.53	1.17	1.97	2.07	**1.70**
I_4 - RDF (150 N:60 P_2O_5 : 60 K_2O kg ha^{-1}	1.47	1.03	2.10	1.47	**1.52**
Mean	**1.57**	**1.25**	**2.18**	**2.00**	
	M x I	**I x M**			
S.Em ±		0.09	0.10		
CD (P=0.05)		0.27	0.32		

accumulation in the crop. Application of RDF alone has resulted in production of lowest straw yield compared to other INM practices during both the years and pooled mean. The interaction between planting methods and INM practices on straw yield was significant during both the years and pooled mean. Interaction effect on pooled mean of straw yield (Table 1d) found that transplanting with Kobota transplanter along with application of FYM @ 5 t ha^{-1} + RDF (M_3I_1) was found best with significantly highest stalk yield over the other combinations and was followed by farmers method of planting along with RDF + FYM @ 5 t ha^{-1} (M_4I_1) .

The benefit cost ratio in rice due to different planting methods, INM practices and their interaction was significant during both the years. (Table 1). In general, B:C ratio values were higher in second year over first year. Among the planting methods, Kobota transplanter method recorded high B:C ratio of 2.0, 2.4 and 2.20 during both the years and pooled mean was on par with farmer method of transplanting during 2011 pooled mean of two years (2.0). The higher B:C ratio was attributed to higher net returns with reduced cost of cultivation as there is labour saving of about 11 man days per hectare. The manual transplanting costs Rs. 23289 ha^{-1} with 67 labours. The results are in conformity with the findings of Manjunatha *et al.* (2009). Followed to this, SRI method of planting attained benefit cost ratio of 1.4,1.8 and 1.6 during both the years and pooled mean and significantly higher than Yangio- China transplanter except during 2011-2012. Among the INM practices, application of RDF+ FYM@5 t ha^{-1} attained significantly higher B:C ratio (1.83, 2.20 & 2.0) during both the years and pooled mean owing to higher grain yield and in turn higher gross and net returns. However, it was on par with application of RDF+GLM@5 t ha^{-1} (2.0) during 2011. Application of RDF+GLM@5 t ha^{-1} fetched next higher B:C ratio (16, 2.0 & 1.8) and significantly higher than RDF+BF @7.5 kg ha^{-1} except pooled mean. The pooled mean of B:C ratio (Table 1e) was significantly higher with Kobota transplanter along with RDF+FYM @5 t ha^{-1} and was on par with RDF+GLM@ 5 t ha^{-1} (2.4.0) and only RDF (2.10) with the same planting method (M_3I_2, M_3I_4) and with farmers method of transplanting with RDF +FYM @ 5 t ha^{-1} (2.37) and RDF+GLM @ 5 t ha^{-1}(2.10).

CONCLUSION

The present study had shown that the mechanical transplanting with Kobota transplanter resulted in higher growth, yield attributes and yield in turn B:C ratio in black soils of Andhra Pradesh compared to Yangi-China transplanter. Complimenting RDF with FYM or GLM @5 t ha^{-1} recorded higher growth, yield attributes, yield and economics of rice. Incorporation of FYM, GLM and bio-fertilisers being socially acceptable, economically viable and environmentally sustainable sources of nutrient application helps in improving and maintaining sustainability of soil and crop productivity.

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EMPIRICAL GROWTH RATE ANALYSIS OF PEARL MILLET PRODUCTION IN NIGERIA: COMPARATIVE ASSESSMENT OF POLICY REGIMES

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ABSTRACT

Growth of agriculture has been linked to sound and laudable agricultural policies and programmes which provide frame work, plan of actions and coordinated activities that seek to achieve self sustaining growth in all the sub-sectors of agriculture and possible realization of the structural transformation of agribusiness environment and value chains. This paper assessed the performance of pearl millet production under various policy regimes in Nigeria using time series data from 1960-61 to 2015-16. Findings from compound annual growth rate indicated that, there was a positive growth in area during period of economic diversification and structural adjustment programme (SAP). Productivity was noted to be high in period of policy of rehabilitation and reconstruction. Log quadratic function in time variable revealed that there was no acceleration in growth of pearl millet production during the studied periods thus, underscoring the policy regimes especially SAP period which recorded decelerated growth. The study advocated yield growth inducing policies in terms of credit and farm input support, enhancement of pearl millet value chain within the prism of agribusiness and infrastructural support.

Agricultural sector plays a vital role in the economy of Nigeria. It contributed to about 42% to the Gross Domestic Product (GDP) and employed about 65 % of the labour force in the country (CBN, 2010, Izuchukwu, 2011 and Sunday *et al*., 2012). There was an uneven performance of this sector in the past. Average annual growth rate ranged from 3.3% in 1990s to about 6.3% from 2000 to 2013. Crops sub sector through production of cereals and root and tuber crops largely accounted for high agricultural GDP, the growth rate has always been attributed more towards the expansion of cultivated land area rather than increase in productivity (Dayo, *et al.,* 2014).

Pearl millet is an important crop among the cultivated cereals in Nigeria grown for both grain and forage purpose. Nigeria produces 40% of the pearl millets grown in Africa and constitutes significant food item especially in the Northern part of the country, occupying almost 10.7% of total cropped area and 13.45 % of total cereals production (Obilana, 2003).

Growth of agriculture has been linked to sound and laudable agricultural policies and programmes which provide frame work, plan of actions and coordinated activities that seek to achieve self sustaining growth in all sub-sectors of agriculture and possible realization of the structural transformation relevant for socio-economic development (Olatunji, 2005; Koyenikan, 2008 and Iwuchukwu and Igbokwe, 2012). Policy makers therefore face challenges to formulate suitable agricultural policies by which the desired growth rate of agricultural output can be achieved. Over the years, successive governments of the country have designed and implemented a myriads of agricultural policies and programmes in an attempt to stimulate the sustainable growth and development of the agricultural sector. Some of these policies were still in place while others have been restructured.

Without studying past performance and trends, the strategic needs of the people cannot be framed meaningfully. This study therefore helps us to assess the progress of pearl millet crop in the light of availing policies and also locate the weakness in planning programmes with a view to draw valid conclusions in the context of raising population. The main objective of the study is to estimate the growth rate in area, production and productivity and the growth pattern in terms of acceleration, deceleration and stagnation of pearl millet production during each policy regime and suggest some policy measures based on findings.

MATERIAL AND METHODS

The study area for this research is Nigeria. A country located in West Africa on the Gulf of Guinea occupying a geographical area of about 923,770 square kilometers with an estimated population of

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182,000,000 (2015 estimate). It lies along latitudes 4° 1' and 13° 9' N and longitudes 2° 2' and 14° 30' E. It is bounded by the Atlantic Ocean to the south and by the Sahelian countries of Niger and Chad Republic to the North and in the west by Republic of Benin. The climate of the country generally falls within the humid tropics, as the country is located close to the equator. The vegetation of the country ranges from mangrove forest on the coast to Sahel savannah in the far north NBS, (2010).

The period of study covers from 1960-61 to 2015-16 and is sub divided into four periods based on policy regimes considering the work of Sanyal and Babu, (2010), Iwuchukwu and Igbokwe, (2012) and Udah *et al.* (2015) to provide basis for comparison. Period I from 1960-61 to 1970-71 (period of policy of economic diversification) explain the period when the nation just got independence and the colonial era policies of export-led growth and diversification of resources to encourage industrialization. Period II from 1971-72 to 1985-86 (period of rehabilitation, reconstruction and stabilization), this period corresponds to period aftermath of the civil war, oil boom and first democratic dispensation; various policies were witnessed in the face of the noticeable decline in agricultural performance. Period III from 1986-87 to 1999-2000 was period of structural adjustment programme (SAP) which marked the beginning of deregulated economy. Policy instruments of SAP were designed to influence the sector indirectly or directly through fiscal policies, monetary, trade and foreign exchange rate policies. Period IV covers from 2000-01 to 2015-16 (period of liberalization) this period marked the beginning of new democratic dispensation and consisted several programmes and policy thrust with an aim of attaining food self sufficiency, increase processing and export of commodities and creation of more agricultural and rural employment.

Data on area, production and productivity of pearl millet were drawn from Food and Agricultural Organization Database (FAOSTAT) and National Bureau of Statistics (NBS). This research adopted a number of models to evaluate how well the policy regimes contributed toward the growth and performance of pearl millet crop. Semi log exponential growth model and Quadratic function in time variable were employed.

Exponential growth model

The exponential form of the model of the following type was used in the analysis to measure the growth rate of the crop during the study period.

$$Y = ab^t + \varepsilon \quad (1)$$

Upon logarithmic transformation the function is converted to linear form

$$lnY = a + bt + \varepsilon \quad (2)$$

Where,

Y = area, production and productivity of the selected crops

t = time variable in years (1, 2, 3… n)

a = intercept (constant)

b = time trend coefficient

Compound growth rate according to Dandekar, 1980 is obtained as follows

$$Y_t = Y_0\,(1 + r) \quad (3)$$

The usual practice is to assume a multiplicative error-term exponential (e) so that the model may be linearized by means of logarithmic transformation giving (for double log);

$$lnY_t = lnY_0 + tln(1 + r) \quad (4)$$

Where,

$$lnY_0 = a$$

$$\ln\,(1 + r) = b$$

Y_t = area, production or productivity

The equation is then fitted to data using method of least squares and goodness of fit is assessed by the coefficient of determination R^2. Finally, the compound growth rate is estimated by differentiating with respect to 't' as follows;

$$\left(\frac{1}{y_t}\right)\left(\frac{dy_t}{dt}\right) = \ln\,(1 + r)$$

$$e^b = 1 + r$$

$$r = expb - 1 \quad (5)$$

Thus, the compound growth rate (r) in percentage is given by;

$$r = (expb - 1) * 100 \quad (6)$$

Where, r = compound growth rate, e = exponential (2.71828) and b = estimated coefficient of time trend.

The standard error (SE) of compound growth rate (CAGR) is estimated by;

$$SE(r) = \frac{100.b}{log^e} SE(lnb) \quad (7)$$

Where, $log^e = 0.4343$

The significance of compound growth rates was tested by using the following formula as follows,

$$t = \frac{r}{SE(r)} \quad (8)$$

Quadratic function in time variable

The present study assessed agricultural policies under different regimes within the study period by fitting quadratic equation in time trend variable on production data to make inference about the pattern of growth whether it is acceleration, deceleration or stagnation as follows.

$$Q_t = \beta_0 + \beta_1 t_i + \beta_2 t_i^2 + U_t \quad (9)$$

Where,

Q_t = quantity of output in different period of policy regime as follows,

Q_t1 = period I from 1960-61 to 1970-71- period of policy of economic diversification

Q_t2 = period II from 1971-72 to 1985-86 - period of policy of reconciliation, rehabilitation, reconstruction and stabilization

Q_t3 = period III from 1986-87 to 1999-2000 - period of structural adjustment programme (SAP)

Q_t4 = period IV covers from 2000-01 to 2015-16 - period of liberalization.

The linear and quadratic time terms indicate the circular path in the dependent variable (Qt) and the quadratic time variable (t^2) allows the possibility of determining whether there is acceleration, deceleration or stagnation in production growth during the study periods. β_0, β_1 & β_2 are parameters to be estimated and consideration is on β_2 which is the coefficient of time trend squared (t^2) that reveals the measure of the growth pattern. The conclusion is that;

If $\beta_2 > 0$ and statistically significant, then there is acceleration in growth,

If $\beta_2 < 0$ and statistically significant, then there is deceleration in growth,

If β_2 is positive or negative but not statistically significant, then there is stagnation in growth

The model was used by many authors including; Sawant, (1983); Oyenweanku, (2004); Nmadu, (2009); Maikasuwa, (2012); Sadiq, (2014); Udah *et al.* (2015) and Isah, *et al.* (2015).

RESULTS AND DISCUSSION

Results of compound annual growth rate

Inter period analysis from the compound annual growth rate of area, production and productivity during the period of study is presented in Table 1. The findings showed varied results in the growth of pearl millet during the periods. Productivity growth rate for instance in period I was very low and statistically not significant, it then increased considerably during period II and became negative in period III, however in the overall period productivity growth increased and was positive at 1% level of significance. High productivity growth (4.7 %) in period of rehabilitation and reconstruction (period II) may be linked to several policy interventions directed to revive the agricultural sector especially in attaining self sufficiency in food production after previous export led policy that gave emphasis on export crops. Inputs supply and distribution policy, creation of ADPs (Agricultural Development Projects) and use of improved seed varieties were among the reasons for this achievement. There was analogously gross declined in area growth during this period (-5.6%) following a positive increase in period I, this negative growth was ostensibly a consequence of labour shift, drought and economic hardship witnessed within this period. Production growth was noted to be negative in period II due to negative growth rate of area.

Period III recorded positive increase in area (3.40%) that resulted in increased production although not statistically different from zero. The growth of area in SAP period was due to several deregulation policies which seemed to initially empower producers. During liberalization period pearl millet registered negative growth rates of area, production and productivity, it was the worst period for pearl millet in terms of production growth and this grossly connected to inadequate inputs support and incidence of Boko

Haram insurgency that ravaged the pearl millet producing areas within this period. There was however positive growth in production and productivity during the country. Average production of pearl millet during that period ranged between 2.5 to 2.7 million metric tonnes.

Table 1. Compound growth rates of area, production and productivity of pearl millet

Period	Area	Production	Productivity
Period I (1960-61 - 70-71)	1.42**(0.0024)	0.67 NS (0.0075)	0.03 NS (0.0049)
Period II (1971-72 - 85-86)	-5.61*** (0.0055)	-0.71 NS (0.0045)	4.70*** (0.0041)
Period III (1986-87 - 99-2000)	3.40***(0.0015)	5.54 NS (0.0016)	-0.04 NS (0.0021)
Period IV (2000-01 - 2014-15)	-6.30***(0.0071)	-3.38 NS (0.0087)	-4.23**(0.0076)
Overall Period (1960-61 - 2015-16)	-1.63 NS (0.012)	1.44***(0.0009)	1.31***(0.0011)

Note: ** and *** indicates significant at 10%, 5% and 1% probability level respectively
NS denotes non significant, while figures in parenthesis are standard errors.

the overall period (1.44% and 1.31%) respectively. Isah, *et al*. (2015) found positive growth rate in area and production of pearl millet between 1982- 2012.

Result of Quadratic equation in time trend variable fitted on production data

Policy of economic diversification (1960-61 to 70-71)

Major features of this policy include conversion of earlier surplus extraction policies during colonial era into the pursuit of an export-led growth. This led to demarcation of the country into the Western Region (cocoa), Northern Region (groundnut) and Eastern Region (oil palm). In this era, there was decentralization and minimum government intervention and also an import substitution policy which saw industrialization as the best strategy to achieve economic growth.

There was stagnant growth in pearl millet production during the policy period (1960-61 to 1970-71) as depicted by the positive and non significant coefficient of time trend (Table 2). The result implied that policies and strategies of export- led growth which emphasized on cash crops production (cocoa, palm oil, rubber, groundnut and cotton) and withdrawal of surplus rural labour to industrial sector caused stagnation of the growth of pearl millet production which was mainly concentrated in the northern part of

Impact of policy of rehabilitation and reconstruction (1971-72 to 1985-86)

This policy era constitutes second and third national development plan period and was characterized by a change of policy from minimal government intervention to maximum in the agricultural sector following huge revenue from oil boom era which brought about enormous financial investments in agricultural projects and institutions. However, since the later half of the 1970s, when oil revenues started to shrink and dependence on imports to cover food shortages were felt insecure, the government altered its policy from one of negligence to one of active encouragement in food production. Many agricultural policies and programmes, fiscal, monetary and trade policies under the macro-economic policies were launched during the era (Ugwu and Kanu, 2012 and Udah, *et. al.,* 2015).

Amidst these reforms and policies during the period, there was stagnant production in pearl millet as evidenced from negative non-significant coefficient of quadratic time trend squared (Table 2). It implied that a number of policies and factors were unfavourable and overweighed the acceleration growth of production. Notable among these, for instance were, the inputs and distribution policy and prioritization of irrigated crops under the RBDAs. Moreover, declined in pearl millet production was generally linked to severe drought experienced in 1972-1974 thus more evidence is seen from compound growth rate which revealed negative growth rate in area and production during this policy phase (Table 1). However, increase in growth of yield rate during subsequent years nullified the acreage effect which was further aggravated by rural-urban migration.

Structural Adjustment Programme (SAP) (1985-86 to 1998-99)

This policy phase came as a last resort when oil price collapsed and the dwindling country's revenues posed threat to fiscal, monetary and agricultural policies. The government admitted the failure of past policies with a view to improve the economy and revive the agricultural sector bedeviled by heavy importation. The objective of SAP was to diversify and restructure the economy, achieve fiscal stability, curve inflation and promote overall economic growth through agriculture. Various programmes and policies were formed during this period some of these include; agricultural extension, technology development and transfer, agricultural credit, agricultural insurance, agricultural mechanization, water resources development policy and rural infrastructure development policies etc.

Pearl millet has registered deceleration growth during SAP period, meaning that the quadratic equation in time variable was negative and statistically significant (Table 2). The crop experienced decline in productivity and production growth while area under cultivation increased marginally (Table 1). This performance indicated the inability of some policies to translate to full positive impacts, among these were marketing and pricing policy - the abolition of marketing boards has resulted in inefficient market structure comprising of more middlemen, inputs and distribution policy was ineffective, supply of improved seed and technology was expensive and beyond farmers access. Available data showed that average production output during this period was 4.5 million tonnes.

Result under policy of liberalization (2000-01 to 2015-16)

The new Nigerian agricultural policy was launched in 2001 by federal ministry of agriculture and rural development following the expiration of the previous policy which designed to be active between 1988 - 2000. The new policy document bears most of the features of the old one, but has more focused direction and better articulation. The objectives of the policy include: (i) The achievement of self-sufficiency in basic food supply and the attainment of food security (ii) Increased production of agricultural raw materials for industries (iii) Increased production and processing of export crops, using improved production and processing technologies (iv) Generating gainful employment (v) Rational utilization of agricultural resources, improved protection of agricultural land resources from drought, desert encroachment, soil erosion, flood and the general preservation of the environment for the sustainability of agricultural production (vi) Promotion of the increased application of modern technology to agricultural production and (vii) Improvement in the quality of life of rural dwellers.

The status of pearl millet production during liberalization period was revealed in Table 2, a stagnation growth was observed as a result of positive but statistically insignificant coefficient of time trend squared variable. The growth rate of pearl millet was worst in this period when compared with other regimes because area, production and yield were all negative. In table 3 further evidence is provided that major source of instability in the period was change in mean area. Although there were favourable policies especially inputs and distribution under NSPFS and Fadama Programmes which provided improved seed varieties, fertilizers and loans to farmers, production was noticed to improved from 1999-2006 in the north east and north west zone which are the major producing zones. However, negative growth and stagnation may be linked to rising prices of inputs, drought and insecurity situation (Boko Haram insurgency) that plagued those areas for quite a protracted period. Available data shows that average annual production of pearl millet during this period stand at 5.2 million metric tonnes.

Table 2. Output (production) growth of pearl millet showing acceleration, deceleration and stagnation during policy regimes

Regimes/crops	Time trend Coeff (β_2)	RS quared	Std. Error	F statistics	Policy Status
Policy of economic diversification (1960-61 to 70-71)	0.0014 NS	0.044	0.0028	0.182	Stagnation
policy of rehabilitation and reconstruction (1971-72 to 85/86)	-0.0009 NS	0.085	0.0012	0.558	Stagnation
SAP period (1986-87 to 1998-99)	-0.0001 **	0.963	0.0004	145.5 ***	Deceleration
Policy of Liberalization 2000-01 to 2015-16	0.0011 NS	0.189	0.0022	1.515	Stagnation

Note: ** and *** indicates significant at 5% and 1% probability level, respectively while NS represent non significant

CONCLUSIONS

The study evaluated the contribution of agricultural policy regimes on the output performance of pearl millet crop using time series data between the period 1960-61 to 2015-16. Findings from compound growth rate of area, production and productivity indicated that, there was a marginal positive increase in area growth during period I (period of economic diversification) and period III (structural adjustment programme). Productivity was noted to be high in period of policy of rehabilitation and reconstruction while in period IV there was decline in area, production and productivity. Decomposition analysis revealed that major reasons for change in the average of pearl millet production were due to change in mean area under pearl millet cultivation followed by interaction effect between change in mean area and mean yield. Similarly, quadratic function further revealed that there was no acceleration growth of pearl millet production during the studied periods; thus, stagnation was recorded in period I, II and IV therefore, underscoring the different policy regimes ostensibly in the area of implementation and other bottlenecks therein. As far as pearl millet production is concerned the findings of this study concluded that structural adjustment programme period has the least structure capable of supporting the production of pearl millet compared to other regimes.

Nigeria has witnessed numerous laudable agricultural policies and programmes designed to achieve food self sufficiency and foreign exchange earnings, however there was still little remarkable achievement and the country continued to remain net importer of some of its food crops. This may grossly be linked due to lack of public participation in the formulation, implementation and evaluation of the majority of the policies, infrastructural decay at both rural and urban centers, meager agricultural capital expenditures and foreign investment, policy instability and inconsistency (Ugwu and Kanu, 2012) In view of this and within the context of the findings of this study, pearl millet crop was seemed to be given less importance by Nigerian government as very few or no specific intervention was noticed considering the importance of the crop in provision of essential diet especially in the northern part of the country. It is recommended that there should be a political will on the part of the policy makers and a coordinated effort in the area of investment in research for more high yielding and more drought resistant pearl millet varieties. Efficient marketing outlet with export consideration that would provide good output price to producers, thus a re-consideration of the abolished marketing board is hereby advocated. There should also be development of infrastructural facilities in core rural areas, availability of inputs, credit and subsidies and the enhancement of pearl millet value chain.

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PROFIT GAIN TRENDS IN MEMBER AND NON MEMBER DAIRY FARM WOMEN UNDER DAIRY COOPERATIVES

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ABSTRACT

A study on the cost economics and profit gain trends in milk production of variable socio economic groups of Mulakanoor women dairy cooperative society resulted in lower average price offered for milk by cooperative compared to the other agencies in study area (Rs. 25-28 for cow milk and 30-40 for buffalo milk vs 22-28 and 30-45 rupees per litre based on fat percentage). Whereas, the overall profit gain from milk production was more in members compared to non-members. The study also established the fact that, as the herd size increased the profit was also increased. The farmers belonging to other castes have earned more profits (Rs. 66.31) compared to weaker sections (Rs. 20.64). Similar trend in profit gain of Rs. 68.51 in large family size and Rs. 121.45 in higher educational level respondents were recorded. Price paid for milk was more in non member group when compared to member group, irrespective of their socio economic variables. The labour utilization was also more in large size family group and the family labour resource utilization was efficient

Dairy farming plays an important role in providing supplementary income, nutritional security and employment among rural women. The cooperative systems are the potential catalyst for mitigating the transaction cost stimulating entry into the market and promoting growth in rural communities. The dairy cooperative movement has transformed the lives of women living in rural India by providing them with some measures of economic and social independence. The cost of milk production is influenced by various factors and it vary from individual to individual and farm to farm which depends upon the judicious utilization of resources available and scientific management of farm dairy animals. There are several agencies and government organizations facilitating and supporting individual farmers to reduce the gap and to increase the production and net income.

Keeping in the view of the above fact the study was undertaken at Mulukanoor Women Dairy Cooperative to analyze the cost economics and profit gain trends depending on certain variables like animal holdings, social status, family size and educational status. The study was also under taken among member and non-member of the societies to assess the advantage of enrolling as shareholders of cooperative societies.

MATERIAL AND METHODS

Forty villages situated around Mulukanoor and covered by cooperative society were selected randomly from four clusters for the present investigation of Mulukanoor Women Co-operative Dairy. Fifty co-operative member producers from each milk cooperative were selected randomly. Similarly, 850 non member producers were selected from milk cooperative area. The cost paid per litre of milk was collected from different agencies and annual administrative and financial reports of MWCD.

The basic tool used for the study was Structured Interview Schedule. The data was collected through personal interviews of the individuals to get valid and complete responses. The data collected by interviewed respondents were coded, classified and analyzed in order to make the findings meaningful. The cost of milk production was derived from the cost per day incurred towards milk production in terms of insurance as animal cost, feed and fodder, labour cost, veterinary and miscellaneous cost. The mean and standard deviation were calculated as per the standard procedures of Snedecor and Cochran (2004). The feed cost included was according to the average price actually paid by the dairy cow owners in the study area. Home supplied feed and fodders were

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also charged according to the local price prevailing in the market. It was assumed that the dairy cow owners had purchased the cow just before calving and sold it after one year. The rate of insurance was calculated at the rate of 5 percent per annum. The return from dairy animals, were included returns from total milk production and also dung value calculated using the following formula.

$$\text{Cost (Rs) of Milk production litre}^{-1} = \frac{\text{Total milk production}}{\text{Total cost (Rs) spent}}$$

Gross income = (Quantity of milk x Prevailing rate of milk + Quantity of dung x Price of dung)

Net income = Gross income – Gross Cost

RESULTS AND DISCUSSION

The price paid to milk in milk shed area of dairy cooperative was based on fat and SNF percentage of milk (two axis pricing policy) and the average price offered to the cow and buffalo milk was Rs. 25-28 and Rs. 30-40 per liter, from societies. Similarly, vendors and private dairies were offering Rs. 25, Rs. 22-28 for cow milk and Rs. 35-45, Rs. 32-38 for buffalo milk whereas, others offered Rs. 25-28 for cow and Rs. 30-40 for buffalo milk. The average price offered to the milk vendors and private dairies was more than that offered to society. Even though the price offered by the society is lower, the majority members preferred to sell their milk to society. This might be due to the stable market, inputs and services offered by the society. Deepak Shah (2000) and Agarwal *et al.,* (2009) also reported that the price paid for milk by the cooperative society was comparatively less than that of milk vendor. Similarly, Ashalatha *et.al*., (2004) also reported that, the price paid by private dairies, local vendors and others for the milk was higher than the cooperatives.

The table 2 reveals that the total cost of milk production was Rs.107.26, 175.00, 203.82 and 261.30 against the returns from sale of milk which was Rs.133.73, 208.68, 272.04 and 450.30 with net return of Rs. 26.52, 33.68, 68.22 and 188.70 in the household possessing one, two, three and four animals, respectively in member women dairy farmers. Whereas, in non member group, the cost of milk production varied from Rs. 91.57 to 224.52 in one to three animals holding. The households who possess three animals were getting maximum returns of Rs. 63.55 per day by spending Rs. 224.52 on milk production with gain of Rs. 288.07 on sale of total milk produced per day followed by Rs. 28.16 and 21.09 as net gain in two and one animal holding, respectively. These results are in comparison with the results of Ashalatha *et.al*., (2004).

The profit gain per day through sale of milk, based on animal holdings was comparatively more in member group than the non member group. Further, it was noticed that as the number of animals per household increased, the profit gain from milk was also increased in both the member and non member groups. The women dairy farmers of the member group producing more milk from dairy animals and thus derived more profits. This might be attributed to genetic potentiality of improved breeds being maintained by member groups which was supported well by dairy society in the form of supply of improved breeds, all services and liberal monetary support for purchase of good germplasm.

In accordance to the social status the cost of milk production was Rs.181.34, 214.77, 191.21 and 180.29 in scheduled caste, scheduled tribe, backward class and other caste women dairy farmers of member group. The returns from sale of milk for these castes were Rs. 229.86, 233.41, 233.90 and 246.60, respectively. The cost of milk production (Rs.) in member women dairy farmers of other caste group was Rs. 180.29 and returns from sale of milk was Rs. 246.60, which was highest among all the four categories of households (Rs. 66.31) whereas, the lowest net gain (Rs. 20.64) was recorded in scheduled tribes followed by backward class and scheduled class. Similar trend was also observed in non member women dairy farmers. The scheduled tribe households has gained minimum net gain of Rs. 18.86 against the cost of milk production of Rs. 194.53 and return from sale of milk was Rs. 213.13 followed by backward class, other caste and scheduled caste households i.e., Rs. 34.01, 47.68 and 47.86, respectively against the cost of milk production of Rs.171.32, 180.72 and 133.54 and returns from sale of milk Rs. 205.33, 278.40 and 181.40 in the respected categories.

The women dairy farmers belonging to other castes derived more profit per day compared to the weaker sections. Ashalatha *et.al*., (2004) and Singh *et.al*., (2000) also observed that the profit gain was higher in other caste dairy farmer. This might be attributed to the low cost input services and feeding nutritionally rich feed, feed supplement, offered by the cooperatives and proper care and management enabling the members to gain more milk yield and profit from their dairy animals compared to non member group. However, the farmers of other castes could get more profit due to more feeding resources available for dairy animals thereby, reducing the cost of milk production.

The cost of milk production in member group women dairy farmers of small family was Rs. 176.54 and it was lower than other group of member. The return from sale of milk was Rs. 215.74 with net gain of Rs. 38.70. The cost of milk production, returns from sale of milk and net gain values were Rs.196.18, 238.67 and 42.49 in medium family groups against the large family with net gain values of Rs.190.92, 259.43 and 68.51, respectively. The non member women dairy farmers with small family size households were gaining minimum net gain of Rs. 29.42 from invested cost on milk production of Rs.137.03 and the returns from sale of milk was Rs.166.46, followed by net profit in medium and large family households (Rs. 39.29, 54.88) against cost of milk production Rs.179.41 and 189.03 and return from sale of milk Rs.218.7 and 243.91, respectively. This indicates that the family labour utilization in dairy farm was efficient in large family group. In the large family group self family labour resources are utilized, which resulted in more profits, these results are in agreement with the results of Meena *et.al*., (2009). On the contrary, Tanwar *et.al*., (2012) reported that the gross return from small families of member and non-member group was maximum.

The cost of milk production in illiterate member group was Rs. 173.98 and returns from sale of milk was Rs. 219.80 with net gain of Rs.45.82. The lowest net gain of Rs. 38.87 was found in women dairy farmers with primary education level (cost of milk production and return from sale of milk was Rs.195.22 and 234.09, respectively) followed by higher secondary, graduate and above qualifications (cost of milk production, returns from sale of milk and net profit values were Rs. 241.33, 344.66 and 103.33, 214.95, 336.40 and 121.45, respectively). The cost of milk production, returns from sale of milk and net profit in non member group was higher in illiterate households (Rs. 40.75) against the cost of milk production of Rs.130.05 and returns from sale of milk Rs.170.30 as compared to the primary standard households with values of Rs. 30.46, 150.52 and 180.98, respectively and no farmers were found with higher educations.

The profit gained by the respondents based on educational status was more with higher education in member group compared to non member group women dairy farmers. This might be due to the adoption of scientific management practices, thereby improving the productivity of animals from educated farmers. The present findings in respect of net returns from the milk per day were in comparison with the findings of Singh and Sharma (2006), Kadian and Gopal Shankala (2009) and Meena *et.al*., (2009). Similarly, the reports of Kumar *et.al*., (2008) revealed that the income from dairy husbandry was positively and significantly correlated with their socio-economic variables namely herd size, family education status, land holding, material possession and employment status.

CONCLUSION

More than 85 percent of the members sold their milk to cooperative whereas, in non member group 80-85 percent sold to milk vendors. Though the price offered by the cooperative is lower when compared to private agencies, the members preferred to sell the milk to cooperative due to stable market and the inputs services offered by cooperative. The profit gain per day through the sale of milk based on socio economic variables was comparatively more in members group compared to the non members. The member women dairy farmers maintained improved breed, more herd size, adopted scientific management practices and received services and inputs from the cooperative which enabled them to gain more milk yield and thus profit from their animals. The education level of farmers showed greater impact on cost of milk production and net gain from sale of milk indicating that technical knowhow and better utilization of resources and inputs helped in reducing the cost of milk production. This also helps in preparation of planning and mode of training programmes to educate the dairy farm women for the utilization of resources at optimum levels and stimulate the non members to become the member of dairy cooperative society and avoid the exploitation from other agencies.

Table 1. Average price (Rs.) offered by different agencies for milk (Per Litre)

Agencies	Cow milk (Rs.)	Buffalo milk (Rs.)
Cooperative society	25-28	30-40
Milk vendors	25.00	35-45
Private dairies	22-28	32-38
Others	25-28	30-40

Table 2. Profit (Rs.) gained per day by respondents based on various socio-economic variables

Variables	Member group			Non member group		
	Cost of milk production (Rs.)	Sale price of milk (Rs.)	Net gain (Rs.)	Cost of milk production (Rs.)	Sale price of milk (Rs.)	Net gain (Rs.)
Animal holding						
One animal	107.26	133.73	26.52	91.57	112.66	21.09
Two animal	175.00	208.68	33.68	174.25	191.41	28.16
Three animal	203.82	272.04	68.22	224.52	288.07	63.55
Four animal	261.30	450.00	188.70	0	0	0
Social status						
Scheduled Caste	181.34	229.86	48.52	133.54	181.40	47.86
Scheduled Tribe	214.77	235.41	20.64	194.53	213.13	18.86
Backward Class	191.21	233.90	42.69	171.32	205.33	34.01
Other Caste	180.29	246.60	66.31	180.72	228.40	47.68
Family size						
Small	176.54	215.24	38.70	137.03	166.46	29.42
Medium	196.18	238.67	42.49	179.41	218.7	39.29
Large	190.92	259.43	68.51	189.03	243.91	54.88
Education status						
Illiterate	173.98	219.80	45.82	130.05	170.30	40.25
Primary	195.22	234.09	38.87	150.52	180.98	30.46
Higher secondary	241.33	344.66	103.33	-	-	-
Graduate and above	214.95	336.40	121.45	-	-	-

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PEARL MILLET ACREAGE SUPPLY RESPONSE IN NIGERIA: A NERLOVE ADJUSTMENT MODEL

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ABSTRACT

Acreage supply response was estimated for pearl millet in Nigeria during the period 1960-61 to 2015-16 using Nerlovian adjustment and price expectation model. The findings revealed that acreage of pearl millet was very low and price inelastic compared to area under cultivation. Similarly, sorghum price and area were significant variables and indicated a complementary relationship with pearl millet, while credit and fertilizer decreased millet area ostensibly due to shift in production. It was inferred from the above that policies during the period of study had favored non price factors for profit motive which spelled badly to food self sufficiency. The study recommended sufficient and timely distribution of inputs (credit, fertilizer improved seed varieties etc), effective pricing policy that would facilitate farming as a business rather than a way of life through creation of commodity board and effective pearl millet value chain.

Agriculture has been the backbone of Africa's economy. The sector accounts for about 20 per cent of Africa's GDP, sixty per cent of its labour force. Most people in sub-Saharan Africa live in rural areas constituting about 61.4% with small farm size (< 5 ha) and low productivity (kg ha^{-1}) compared to many asian developing countries (ECA, 2007; Nchuchuwe and Adejuwon, 2012 and Dercon and Gollin, 2014).

In Nigeria agricultural sector plays a vital role in growth and development of the economy. The sector contributes significantly to about 40% of the gross domestic product (GDP) and employed about 86 percent of the rural households and 65-70 per cent of the labour force in the country (CBN, 2010; Fan *et al.,* 2008 and Sunday *et al.,* 2012). It is obvious that improvement in the agricultural development and growth can offer a pathway from rural poverty, but evidence-based macroeconomic policies and instruments are prerequisite. The performance of the agricultural sector was uneven in the past with its average annual growth rate ranging from 3.3% in 1990s to 7% between 2003 and 2013. Most of the current growth rate has been attributed more to expansion in cultivated land area rather than increase in productivity (Sanyal and Babu, 2010; Xinshen, *et al*. 2010 and Phillip *et al.,* 2014). Crop production in Nigeria is dominated by cereals, root and tuber crops.

Understanding how producers make decisions to achieve a desired crop output enticed by impact of output price expects to have critical policy makers. The concept of supply response is an important issue as responsiveness of farmers to economic incentives largely determines the contribution of agriculture to the economy, this is by adopting suitable pricing policy and assessment of farmer's behaviors with respect to increase in area under cultivation and other supply shifters. Economic theory suggests that, prices are significant determinants of economic behavior and normal producer should adequately react to changes in prices of output (Orefi, *et al.,* 2015). Reliable estimates of these elasticities are sine qua non for predicting accurately the farmer responsiveness to changes in input-output prices and government public investment and thereby formulating successful agricultural intervention programmes consistent with national requirements (Tripathi, 2008 and Ullah *et. al*. 2012).

The study therefore seek to estimate the acreage response of pearl millet crops in relation to price and others determinants so as to draw policy direction that will stimulate production and meet the growing demand of increasing population

METERIAL AND METHODS

The study area for this research is Nigeria located in West Africa on the Gulf of Guinea. Data for this study was time series drawn from Food and Agricultural Organization Database (FAOSTAT) and National Bureau of Statistics (NBS) covering a period of 56 years from 1960-61 to 2015-16.

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Analytical framework

Nerlove M. (1958) developed two distributed lag models and attempted to estimate the elasticity in supply of corn, cotton and wheat in U.S.A. From adjustment and partial expectation model, the desired acreage A_t^d is a function of price expectation P_t^e in period t, while the actual acreage A_t adjusts to the desired acreage with some lag. The equations can be expressed as follows:

$$A_t^d = \beta_1 + \beta_2 P_t^e + \beta_3 Z_t + U_t \quad (1)$$

$$P_t^e = P_{t-1}^e + \alpha(P_{t-1} - P_{t-1}^e) + V_t \quad (2)$$

$$A_t = A_{t-1} + \gamma(A_t^d - A_{t-1}) + \omega_t \quad (3)$$

Equation (1) showed the relationship that, desired acreage depends on the expected price and other exogenous shifters (Z_t) i.e. other non price factors like rainfall, infrastructures, credits, yield risk, technology etc. β_2 is the short run elasticity coefficient with respect to price and U_t is the unobserved error term affecting supply with zero mean and constant variance.

The actual area response is assumed to differ from the desired ones because of the adjustment lags of some variable factors occurring in the long run, therefore the actual acreage response 'A_t' would only be a fraction of the desired acreage A_t^d

$$A_t - A_{t-1} = \gamma(A_t^d - A_{t-1}) + \omega_t$$

Rearranging gave us equation 3

Where, A_t is the actual acreage response in period t, A_{t-1} is the actual acreage lagged by one year, A_t^d is the desired acreage response in the period t and γ is the partial adjustment coefficient representing the fraction of the change between two periods. If the adjustment coefficient is close to 1, then it implies that, farmers' adjustments of actual acreage to desired acreage is fast. If the adjustment coefficient is close to zero, then the adjustment takes place slowly.

Similarly, in the price expectation model farmers react not only to previous year's prices, but also to the price they expect and this expected price depends to a limited extent, on the previous price. Prices were revised in each period in proportion to the difference between the last period's actual price and the previous expectation, that is the error they made in predicting the price (adaptive based on actual and expected). The behaviour is depicted as,

$$P_t^e = P_{t-1}^e + \alpha(P_{t-1} - P_{t-1}^e) + V_t$$

Rearranging:

$$P_t^e = P_{t-1}^e + (1-\alpha)P_{t-1}^e + V_t$$

Where, P_t^e is the expected price in period t, P_{t-1}^e is the price that prevails when the decision making occurs and α is the adaptive expectation coefficient also known as price elasticity which ranges between $0 < \alpha > 1$

Hence, by combining equation 2 and 3 and eliminating the unobservable variables A_t^d and P_t^e gives the structural reduced form of the model as;

$$A_t = \delta_1 + \delta_2 P_{t-1}^e + \delta_3 A_{t-1} + \delta_4 Z_t + e_t \quad (4)$$

Where;

$\delta_1 = \beta_1 \alpha\gamma$

$\delta_2 = \beta_2 \alpha\gamma$

$\delta_3 = (1-\alpha) + (1-\gamma)$

$\beta_2 = \delta_2 / (1-\delta_3)$

Co efficient of short run elasticity = δ_2

Co efficient of speed of adjustment = δ_3

Coefficient of long run elasticity = β_2

$e_t = V_t + \omega_t$

To achieve the stated objective, the study identified both price and non-price factors that affect farmers decision pertaining to area allocation of the selected crops. The price factors constitutes own price of the crop and price of competing crops. Non price factors include; rainfall, credits, fertilizer consumption, lagged area of the crop, yield of the crops and time trend to capture the effect of technology. Based on these variables and equation (4), the frame work is modeled as follows;

$$lnA_t^{millet} = \beta_0 + \beta_1 lnP_{t-1}^{millet} + \beta_2 lnA_{t-1}^{millet} + \beta_3 lnMl_{t-1}^{yield} + \beta_4 lnP_{t-1}^{sorghum} + \beta_5 lnSg_{t-1}^{area} + \beta_6 lnCR + \beta_7 lnFert + Vt \quad (5)$$

Where,

P_{t-1}^{millet} = Price of millet lagged by one year in Naira per ton

A_{t-1}^{millet} = Millet area lagged by one year in hectares

Ml_{t-1}^{yield} = Millet yield lagged by one year in Kg per hectare

$P_{t-1}^{sorg\,hum}$ = Sorghum price lagged by one year in Naira (local currency)

Sg_{t-1}^{area} = Sorghum area lagged by one year in hectares

CR = Credit to food crops in Naira

$Fert$ = Fertilizer consumption (NPK) in tonnes

ln = Natural logarithm while, $\beta_1 \ldots . \beta_n$ are coefficients to be estimated.

RF = Average annual rainfall in mm

RESULTS AND DISCUSSION

Acreage response of millet as depicted in Table 1 showed that the model explained about 88 percent of the total variations in the dependent variable as depicted by the coefficient of multiple determination. The results indicated that lagged area of millet, price of sorghum, lagged yield of pearl millet, lagged area of sorghum and credit were significant factors influencing millet area allocation. Area under millet was found to be increasing over time. One percent increase in lagged dependent variable caused 0.6 percent increase in area allocated in period t. The crop occupied 13.45 percent of total cereals production and predominantly grown in the northern zones of the country where land is readily available, farmers increased area allocation perhaps due to positive effect of yield as pearl millet price was though positive (0.09) but found to be insignificant factor. It means that millet producers were not responsive to price incentive, this is contrary to theoretical expectation. Possible reason may seem to be a tradeoff with sorghum price. Lagged millet yield was found to be significant at 1% level indicating that, a unit increase *ceteris paribus* increases area under millet by 0.3. The positive effect of yield may be linked to the introduction of high yielding varieties of millet like SOSAT C 88 and INMV 55 by ICRISAT and IAR, Zaria.

Lagged price and lagged area of sorghum exhibited a positive significant relationship with millet acreage, implying that sorghum is not a competing crop but a complementary crop. This was evident as the crop is mostly planted together with millet. As price of sorghum increases by 1%, area under millet also increases by 0.3%, Similarly, 1% increase in sorghum area causes area under millet to increase by 0.5 percent. Two other non price variables included in the model were credit and fertilizer consumption and both variables impacted negatively on millet acreage response which was contrary to economic theory. This implied that farmers will shift to other production or businesses as more of credits or fertilizers are obtained. The area under millet decreased by 0.4%, as the credit increased by 10%.

The low and non significant value of lagged price of millet indicated that price does not determine or is not an important variable in millet acreage supply response, and this may suggest the subsistent nature of the crop generally produced for immediate consumption by majority of the producers. Abdullah, *et al.* (2006) found negative insignificant relationship using output as proxy from the period 1970 to 2002 in Borno and Yobe state of Nigeria. While in Niger Republic, Akinwumi and Brorsen, (1987) reported own price elasticity of 0.4 during the study period of 1976 to 1983. However, non price factors clearly influenced farmers' decision on millet acreage response. The long run price elasticity was found to be higher (0.25) than the short run and this was in line with literature. Similarly, the number of years required for 95% price effect to materialize was estimated to be 6.02 years. Diagnostic check showed that R squared was good, 88% variation was accounted by the explanatory variables and model was devoid of autocorrelation as indicated by h statistics (2.08).

The null hypothesis of price significantly causing supply could therefore be rejected at the altar of non price factors.

$$lnA_t^{millet} = 0.09Mlprice + 0.61Mlarea + 0.28Mlyield - 0.26Sgprice + 0.49Sgarea - 0.04Cred - 0.03Fert - 3.06C$$

Table 1. Acreage response function for Millet in Nigeria 1960-61 to 2015-16

Particulars/Variables	Coefficient	Standard Error
Constant	-3.0601 *	1.6944
Lagged price of pearl millet	0.0964 NS	0.1355
Lagged area of Pearl millet	0.6097 ***	0.0815
Lagged yield of Pearl millet	0.2812 ***	0.0708
Price of Sorghum	0.2612 *	0.1404
Lagged area of Sorghum	0.4917 ***	0.0921
Credit	-0.0424 ***	0.0135
Fertilizer	-0.0339 NS	0.0223
Long run price Elasticity	0.25	
R^2	0.88	
F statistics	38.3 ***	
DW statistics	2.26	
Breusch-Pagan test	0.192	
h statistics	2.08	

Source : Author's own computation. ***, **, * denotes significance at 1%, 5% and 10%, respectively NS indicated not significant

CONCLUSIONS

Acreage supply response was estimated for pearl millet in Nigeria using time series data from 1960-61 to 2015-16. Nerlovian adjustment and price expectation model was employed to determine the elasticities with respect to price and other factors. The findings revealed that price was not an important variable in pearl millet supply response as compared to area which has higher elasticity and was highly significant. Similarly, farmers considered own lagged yield, sorghum price and sorghum area in their allocation decision. Whereas, pearl millet output decreased during the period due to misapplication of credit and fertilizer as there was shift in production. It can be inferred from above that policy towards better profit for farmers as a priority incentive if there was any, could not achieve the desired goal. The study therefore recommends a special market intervention that would guarantee a minimum support price to producers to ensure more profit and make farming a business rather than a way of life. Imperatively, value chain of the crop need to be facilitated and actors along the chain should ensure sustainable production by partnering with government in research and extension delivery, while credit and inputs supply should be sufficient and timely.

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EFFECT OF *SACCHAROMYCES CERVISIAE* ON SERUM BIOCHEMICAL PROFILE IN JAPANESE QUAILS

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ABSTRACT

The objective of this study was to investigate the effect of supplementation of Dietary baker's yeast *Saccharomyces* cervisiae (single cell protein) as a probiotic on biochemical profile of Japanese quails (*Coturnix* coturnix japonica). In this experiment a total of 96 day-old unsexed, Japanese quails were equally divided into three groups of 32 birds in each group. The standard basal diet was fed in first group (G1), 5% and 10% level of baker's yeast was supplemented in basal diet for second group (G2) and third group (G3), respectively. Feed and water was supplied *ad libitum* for all the birds. At the end of the experiment blood samples were taken to determine some blood plasma constituents. The results obtained in this study showed that, supplementation of dietary baker's yeast had positive effect on blood biochemical profile in Japanese quails.

Probiotics are living microorganisms which are mainly derived from certain bacteria, fungi and yeast cell. Yeast (*Saccharomyces cervisiae*) is one of the most widely used probiotics. It has been fed to animals and poultry. Yeast is a 'single cell protein' the production is originated in Germany during World War-I, when the baker's yeast, was grown with molasses as the carbon, energy and nitrogen source for consumption as a protein supplement. Use of probiotics, prebiotics and organic acids instead of antibiotics has increased in recent times. Probiotics act by competitive exclusion, lower gut pH, produce bacteriocins, lysozyme and peroxides, and stimulate the immune system (Grasharn *et al.*, 2010). Some of the probiotic products contain *Sacharomcyces* spp. *Saccharomyces cerevisiae*, from malted grains fermentation also known as ''baker's yeast'' is one of the most widely commercialized types of yeast, has long been fed to animals (Rezaeipour *et al.*, 2012). Moreover, yeast products are important natural growth promoters (Gao J *et al.*, 2008). Yeast *Saccharomyces cerevisiae* is rich source of protein, vitamin B complex, trace minerals and many other beneficial factors (Reed G *et al.*, 1991). Yeasts may beneficially alter the inherent gut microbiota, possibly through controlling pH. The presence of living yeast cells may also act as a reservoir for free oxygen, which could enhance growth of other anaerobes (Leeson S *et al.*, 2008). Some studies have confirmed the effects of yeast culture in increasing concentrations of commensal microbes or suppressing pathogenic bacteria (Stanley VG *et al.*, 2004). Mannan-oligosaccharide and 1,3/1,6 β-glucan are components of the yeast cell wall that have been reported to modulate immunity (Shashidhara RG, *et al*., 2003), promote growth of intestinal microflora and increase growth (Parks CW, *et al.*, 2001). Yeast culture contains viable cells, cell wall components, metabolites, and the media on which the yeast cells were grown (Miles RD *et a.l*, 1991). In in vitro study, (Jensen GS *et al*., 2008), postulated that the addition of a soluble fraction of yeast culture showed an anti-inflammatory effect in conjunction with activation of natural killer cells and B lymphocytes. In addition, others have reported that yeast products affect nutrient digestibility (Brandley GL *et al.*, 1995) and intestinal mucosal development (Santin E *et al.*, 2001). These properties led researchers to use yeast culture as probiotic feed additives in Japanese quails diet.

Japanese quails (*Coturnix coturnix japonica*) have become an important alternative poultry species because it has a small body size, easy to handled, large number of birds can be kept in a limited space, high egg production, many offspring can be available from certain number of parents. It is also used in embryological studies (Ayasan and Okan, 2001). Quail eggs are rich in protein and good source of iron, phosphorus, riboflavin and selenium (Bing, 2011).

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There are limited number of studies reported on effect of dietary yeast on blood biochemical profile in Japanese quails. Therefore, the present study was conducted to investigate the effect of supplementation of dietary baker's yeast as a probiotic on blood biochemical profile of Japanese quails

MATERIAL AND METHODS

In this study, a total of 96 days healthy old quail chicks were randomly assigned to 12 cages of 8 birds each and cages were allocated to three groups with four replication per treatment. The birds were maintained under uniform condition and housed in standard cages (40x40x25 cm^3) in a temperature controlled house at 35^{o}C. All the birds had free access to feed and water. The photoperiod was 16 hrs (Vatsalya and Kashmiri, 2011). Prior to the supplementation of yeast in the experimental diets, all the birds were fed *ad libitum* for first week for acclimatization. All the diets were Isocaloric and Iso nitrogenous (Table 1). The birds of three groups were fed with experimental diets in the first group (T_1) was fed with control/basal diet second group (T_2) was fed with 5% of baker's yeast in the basal diet and in third group (T_3) was fed with 10% of baker's yeast in the basal diet (Table 2). The experiment lasted for 5 weeks.

At 6 weeks of age, blood samples from randomly 8 birds of each treatment, were collected from the wing vein in heparinized tubes and centrifuged at 3000 rpm / 20 minutes. The serum was obtained and immediately stored at -20^0 C till analysis. Total protein, albumin, total lipids and SGOT and SGPT were determined by biochemistry kit methods (Accurex Autozyme). The total globulin values were calculated by subtracting the values of total albumin from total protein for each sample.

Data were statistically analyzed using the analysis of variance. Significant difference between treatment means were calculated according to Snedecor and Cochran (1980).

Table 1. Ingredients and chemical composition of basal diet:

Ingredients	grams
Maize	548.560
Soya bean meal	401.350
Salt	4.000
Di calcium phosphate	10.760
Stone grit	12.260
DL-Methionine	1.410
AB2D3K	0.150
B-complex	0.150
Choline chloride	0.150
Toxin binder	2.000
Trace Minerals mixture	1.200
Oil (Veg)	17.660
Coccidostat	0.500
Crude protein (%)M	23.000
etabolic energy (Kcal/kg)	2900.000
Calcium (%)	0.8000
Phosphorus (%)	0.3000

RESULTS AND DISCUSSION

The feed ingredients used in the control group and treatment group were same but 5% and 10% level of yeast was supplemented in group-2 and group-3, respectively.

The biochemical changes in plasma total protein, albumin, globulin, total lipids, SGOT and SGPT were studied in this experiment. The data illustrated in table 2 indicated that, supplementation of 10% yeast to Japanese quails diet enhanced significantly (P>0.05) plasma total protein and albumin compared to control diet. However, significantly higher (P>0.05) plasma albumin value was noticed when quails fed diet contain 5% of yeast. The greatest improvement (P>0.05) in globulin was recorded when quails fed dietary yeast at 10%.

Table 2. Effect of dietary treatments on plasma biochemical profile

Item	Treatments		
	Control group	5% yeast	10% yeast
Total Protein (g dL^{-1})	3.45^{c} ± 0.03	3.617^{b} ± 0.02	4.503^{a} ± 0.08
Albumin (g dL^{-1})	2.280^{c} ± 0.009	2.637^{a} ± 0.45	2.445^{b} ± 0.25
Globulin (g dL^{-1})	1.170^{c} ± 0.007	1.867^{b} ± 0.054	2.202^{a} ± 0.24
Total Lipids (mg dL^{-1})	702.7^{a} ± 0.05	678.0^{b} ± 4.71	669.7^{b} ± 1.02
SGOT (U L^{-1})	138.6^{a} ± 1.127	123.2^{b} ± 3.08	115.3^{b} ± 2.02
SGPT (U L^{-1})	166.7^{a} ± 0.019	142.3^{b} ± 0.54	151.0^{b} ± 0.16

The data illustrated in table : 2 revealed that, the lowest (P>0.05) values of total lipids and SGOT were observed when birds fed diets contain 5% level of yeast. However, no significant difference (P>0.05) in total lipids and SGOT were detected by dietary addition of yeast at 10% level. The plasma SGPT values were decreased significantly (P>0.05) when quails fed with 5% level of yeast compared to control diet, however there was no significant difference of SGPT when birds fed on 10% dietary yeast.

The positive effect on plasma total protein, albumin, globulin, total lipids, SGOT and SGPT is due to increased number of anaerobic and cellulytic bacteria when the experimental diet was supplemented with yeast which enhanced lactate utilization and moderate pH of gut, therefore, yeast improves the nutrients digestibility and growth performance, revealed that dietary supplement of yeast (S. *cerecisiae*) improves the body performance and blood biochemical profile in broilers. These above results may explain the significant effects of dietary yeast in improving the metabolic process.

CONCLUSION

Dietary yeast has great potential to beneficially affect the gut microflora and hence improves digestibility and health in Japanese quails. The present study confirms that, the supplementation of bakers yeast as a probiotic in growing Japanese quails diets significantly improved the blood biochemical profile. It could be concluded that, dietary yeast to growing quails up to 10% level improved the blood biochemical profile.

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PRODUCTION AND REPRODUCTION PERFORMANCE OF NELLORE SHEEP IN (NATIVE BREEDING) CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The analysis of field data on 1350 Nellore Jodipi sheep maintained by farmers under field conditions of Andhra Pradesh revealed that the effect of division and sex had significant ($P \leq 0.01$) influence on body weights at majority of ages studied. The overall least square means for body weight at 2, 4, 6 and 8-teeth age were 35.26 ±0.23, 38.45 ±0.13, 39.53 ± 0.32 and 40.06 ± 0.33 kg, respectively. Males were heavier than females in all age groups and the differences of body weights were 10.67, 10.44, 8.84 and 7.37kg, respectively at 2, 4, 6 and 8-teeth ages. The overall least squares means for age at first service, age at first lambing, lambing interval and gestation period were 689.09 ± 1.23 days, 841.04 ± 1.21 days, 383.43 ± 0.48 days and 151.95 ± 0.08 days, respectively.

Sheep is one of the important species of livestock contributing to the livelihood of resource poor farmers of rural areas in arid and semi arid regions of India. India has about 73.99 million (FAO, 2010.) sheep population and ranks third in the world with 42 recognized sheep breeds. While, Andhra Pradesh ranks first in the country with 255.39 lakhs sheep (Livestock census, 2007) population consisting of Nellore, Deccani and Bellary recognized sheep breeds. Nellore is a popular and tallest mutton breed in the country distributed predominantly in Nellore, Prakasam, Chittoor districts of Andhra Pradesh . It contributes to the farm households not only by acting as a source of livelihood but also as a moving asset, which can be liquidated during crisis periods. Therefore, present study was initiated with the main objective of study of field performance of Nellore sheep in native breeding tract for evaluation and improvement.

MATERIAL AND METHODS

Stratified random sampling technique was applied for selection of mandals, villages, farmers and animals in Chittoor district for collection of data. The district was divided into four divisions namely Chittoor, Tirupati, Puttur and Madanapalli for administration purpose. Out of 66 mandals in the district, 12 mandals (18%) were selected randomly. From each division three mandals and from each mandal three villages were included in the study.

The data was recorded on body weights of 1350 animals of different ages from 144 farmers' flocks spreaded in 12 mandals and 36 villages. The data on reproductive performance of 1190 adult female sheep belonging to different age groups were collected in the morning before the animals were left for grazing. The data on age at first mating, age at first lambing, lambing interval were recorded on ewes present in the farmers flock by interviewing the owner. The age particulars of animals were not available in the field conditions, the eruption of permanent incisor teeth (dentition) was taken as an indicator of age of the animal (Turner 1937). Body weights of animals of farmer's flock were recorded with the help of a spring balance.

Statistical analysis:

The data on body weight were grouped according to the division and sexes and were subjected to least squares technique (Harvey 1987) to study the influence of division and sex on body weight using the following statistical model.

$Y_{ijl} = \mu + D_i + S_j + e_{ijl}$ Where,

Y_{ijl} = The measurement on 1^{st} animal belonging to j^{th} sex and i^{th} division.

μ = Overall mean

D_i = Effect of i^{th} division (I = 1 to 4)

1 = Chittoor division 3 = Puttur division

2 = Tirupati division 4 = Madanapalli division

S_j = Effect of j^{th} sex (j=1 for male and 2 for female)

e_{ijl} = random error.

RESULTS AND DISCUSSION

The overall least square mean body weights at 2, 4, 6 and 8- teeth age were 35.26 ± 0.23, 38.45 ±0.13, 39.53 ± 0.32 and 40.06 ± 0.33 kg, respectively.

Division had highly significant (P≤0.01) effect on body weight at all ages studied. The mean body weight varied from 34.66 (Madanapalli) to 35.72 (Tirupati), 37.98 (Madanapalli) to 39.38 (Tirupati), 38.77 (Chittoor) to 40.84 (Tirupati) and 38.94 (Madanapalli) to 40.97 kg (Tirupati), respectively at 2, 4, 6 and 8- teeth ages. The variation in body weights of Nellore sheep in different divisions could be attributed to the differences in availability of grazing material, forest area and management practices followed among different division in Chittoor district.

The effect of sex on body weights at all ages studied was highly significant (P≤ 0.01). The mean body weights of rams at 2, 4, 6 and full mouth age were 40.56 ± 0.57, 43.67 ± 0.23, 43.95 ± 0.62 and 43.70 ± 0.65 kg respectively, while in ewes the corresponding body weights were 29.92 ± 0.13, 33.27 ± 0.14, 35.11 ± 0.14 and 36.33 ± 0.13 kg, respectively. Males were heavier than females in all age groups and the differences of body weights were 10.67, 10.44, 8.84 and 7.37 kg, respectively at 2, 4, 6 and 8-teeth of ages. The variation of body weights at different ages among males and females are probably due to the hormonal influence and the dominant and aggressive behaviour of males while grazing.

The mean body weights recorded in present study are similar to the findings of Verma *et al*. (2005) in Marwari, Arora *et al*. (2007) in Jaisalmari and Kumar *et al*. (2008) in Malpura sheep. While the body weights of Nellore sheep were higher than the published information on Deccani (Narasimham, 2003 and Sreenivasu *et al*. 2003), Madras Red (Raman *et al*. 2003), Ramnad White (Kumarvelu *et al*. 2009).

The overall least square means for age at first service was 689.09 ± 1.23 days and varied from 685.3 ± 2.69 (Madanapalli) to 692.27 ± 2.23 days (Chittoor) among four divisions (Table 2). The division had no influence on age at first service. These findings were in concurrence with Kandasamy *et al*. (2006) in Coimbatore, Kumar *et al.* 2008 in Malpura, Kumarvelu *et al*. 2009 in Ramnad White.

In the present study, geographical location had no influence on age at first lambing interval. The overall least squares mean for age at first lambing was 841.04 ± 1.21 days and ranged from 837.19 ± 2.695 (Madanapalli) to 844.13 ± 2.12 (Chittoor). The overall least squares mean for lambing interval was 383.43 ± 0.48 days and ranged from 382.73 ± 0.94 (Chittoor) to 384.83 ± 0.99 (Madanapalli) among four divisions (Table 2). The variation among divisions could be the differences in plane of nutrition and management practices. The means recorded in the present study are in accordance with the findings in Deccani sheep (Annual Report, 2003). The age at first lambing in earlier studies was reported as, 794.85 days by Purushotham (1972) and 943 days by Reddy (1980) in Nellore sheep of Andhra Pradesh.

The overall least squares mean for gestation period was 151.95 ± 0.08 days and it varied from 151.86 ± 0.16 (Chittoor) to 152.06 ± 0.18 days (Madanapalli) among four divisions. Davison had no significant influence on gestation period. The present results are in accordance with the findings of Reddy (1980) in Nellore sheep.

Table 1. Least-squares means of Body weights (Kg) of Nellore sheep at different ages

	2 teeth			4 teeth			6 teeth			8 teeth		
	n	Mean	S.E	n	Mean	S.E	n	Mean	S.E	n	Mean	S.E
Overall	321	35.26	0.23	411	38.45	0.13	210	39.53	0.32	308	40.06	0.33
Division		*			**			**			**	
Chittoor	82	35.37^{bc}	0.36	106	38.15^{ab}	0.25	79	38.77^{a}	0.41	77	39.77^{a}	0.42
Tirupati	78	35.72^{c}	0.36	100	39.38^{c}	0.25	74	40.84^{c}	0.42	72	40.97^{b}	0.43
Puttur	73	35.27^{ab}	0.38	103	38.28^{b}	0.24	76	39.62^{b}	0.40	85	40.38^{b}	0.34
Madanapalli	88	34.66^{a}	0.36	102	37.98^{a}	0.25	81	38.87^{ab}	0.38	74	38.94^{a}	0.42
Sex		**			**			**			**	
Male	16	40.59^{b}	0.57	114	43.67^{b}	0.23	16	43.95^{b}	0.62	14	43.70^{b}	0.65
Female	305	29.92^{a}	0.13	297	33.23^{a}	0.14	294	35.11^{a}	0.14	294	36.33^{a}	0.13

* Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$ n=number of animals
Means followed by the same super script(s) do not differ significantly

Table 2. Least-squares Means of Reproductive traits (days)

		A F S		A F L		L I		G P	
	n	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S. E
Overall	1190	689.09	1.23	841.04	1.21	383.43	0.48	151.95	0.08
Division									
Chitoor	312	692.27	2.23	844.13	2.12	382.73	0.94	151.86	0.16
Tirupati	295	689.72	2.44	841.72	2.38	383.15	0.93	152.00	0.18
Puttur	291	688.83	2.50	840.89	2.46	383.05	1.00	152.06	0.18
Madanapalli	292	685.30	2.69	837.19	2.65	384.83	0.993	151.89	0.16

AFS = Age at First Service, AFL = Age at First Lambing,
LI = Lambing Interval, GP = Gestation Period

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Research Notes
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YIELD AND YIELD ATTRIBUTES OF *Bt* COTTON AS INFLUENCED BY DIFFERENT DRIP FERTIGATION SCHEDULES

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Cotton (*Gossypium* spp.) popularly known as "white gold", is an important commercial fibre crop which plays an important role in livelihood of around 250 million people globally and it accounts for 75 per cent of the fibre used in the textile industry in India. India is the largest cotton growing country in the world with an area of 119.27 lakh ha. The area of cotton in Telangana is 18.13 lakh ha with productivity of 423 kg lint ha^{-1} which is lower compared to national average productivity of 487 kg lint ha^{-1} (DoES, 2015). Water and fertilizers are important critical input factors for cotton production. The lower yields of cotton could be attributed to inefficient irrigation and fertilizer management practices (Veeraputhiran and Chinnusamy, 2009). Drip fertigation, therefore, is the new approach for water and nutrient management as the nutrients and water are applied directly into the soil, where the roots are actively growing and found to increase the efficiency of fertilizer use. Hence, the experiment was planned to study the nitrogen and potassium fertigation schedules on yield and yield attributes of *Bt* cotton under different fertigation schedules and irrigation regimes.

A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *kharif* 2015-16. The experiment was conducted in a randomized block design replicated thrice with nine treatments composing of drip irrigation scheduled at 0.8 Epan replenishment throughout life, 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of N & K in equal splits or differential dosage once in 3 or 7 days from 10 to 115 days after sowing (DAS) in 35 and 15 splits, respectively and furrow irrigation at IW/CPE ratio of 0.8 and application of recommended dose of fertilizer (RDF) to soil as conventional method in equal four splits (N and K) at 20, 40, 60 and 80 DAS and P as basal (Table 1). RDF was 150: 60: 60 N, P_2O_5 and K_2O kg ha^{-1}, respectively and P was applied as basal to all treatments. The experimental soil was high in available phosphorous, low in available potassium and organic carbon content. *Bt* cotton (KCH-14K59.BG II) was sown with a spacing of 120 cm x 45 cm on 22nd June 2015 and final harvest was done on 12th January 2016 with four times cotton picking from 105 DAS onwards at 25 days interval. The total amount of rainfall during the crop growth period was 386.4 mm, received in 29 rainy days. The experiment was conducted with inline drip irrigation system with lateral spacing of 120 cm and drippers of 40 cm apart having a plot size of 7.2 × 14.4 m. Lateral valves and venturi were fixed to apply the fertilizers as per the treatments. Nitrogen and potassium was applied through irrigation water by urea and sulphate of potash as per the treatments applying standard procedure and precautions.

The results obtained indicated that yield attributes *viz.,* number of bolls $plant^{-1}$, boll weight, yield $plant^{-1}$, seeds $boll^{-1}$ and seed index (100 seed) were influenced significantly by different drip fertigation and irrigation schedules (Table 1). Number of bolls $plant^{-1}$ and boll weight recorded with drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage once in 3 days (84.2 and 5.0, respectively) was significantly superior than rest of treatments (boll weight was on par with 0.8 Epan throughout life and fertigation of equal splits once in 3 days) and furrow irrigation at 0.8 IW/CPE ratio recorded significantly lower total number of bolls $plant^{-1}$ (56.7) and boll weight (3.91g) was significantly on par with 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of equal splits once in 7 days (62.2). A mean increase of 78.3 and 27.9 per cent and 42.5 and 25.8 per cent in number of bolls $plant^{-1}$

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and weight, respectively with 0.8 Epan throughout life and fertigation once in 3 days of differential dosage or equal splits, respectively was observed compared to furrow irrigation at IW/CPE ratio of 0.8 and application RDF to soil. Similar reports on significantly higher boll number under drip irrigation than conventional method was reported by Nalayini *et al.* (2006). Mean boll weight and seeds boll^{-1} of *Bt* cotton varied from 3.9 to 5.0 g and 27.1 to 36.3. Compared with furrow irrigation at IW/CPE ratio of 0.8 and application RDF to soil there was a mean increase of 27.9 per cent and 25.8 per cent in number of bolls with 0.8 Epan throughout life and fertigation once in 3 days of differential dosage or equal splits, respectively.

Significantly higher number of seeds boll^{-1} (36.3) and seed index (8.60 g) of *kharif Bt* cotton was observed with drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage once in 3 days than rest of the treatments except drip irrigation at 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of differential dosage once in 3 days (35.5 and 8.09) and 0.8 Epan throughout life and fertigation of differential dosage once in 7 days (35.4 and 8.23). seeds boll^{-1} (27.1) and seed index (7.08 g) recorded with conventional method of furrow irrigation at IW/CPE ratio of 0.8 Epan and RDF applied to soil was significantly lower and statistically differed with rest of the treatments.

Seed cotton yield plant^{-1} of *kharif Bt* cotton ranged from 127.5 to 204.7 g plant^{-1} in different treatments with a mean of 177.4 g plant^{-1} and drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage once in 3 days registered (204.7) on par with 0.8 Epan throughout life and fertigation of equal splits once in 3 days or differential splits once in 7 days and 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of differential dosage once in 3 days and significantly higher than rest of the treatments. There was a mean increase of 60.5 per cent and 53.6 per cent in seed cotton yield plant^{-1} with drip irrigation scheduled at 0.8 Epan throughout life and fertigation once in 3 days of differential dosage or equal splits, respectively over furrow irrigation. Similar findings were also reported by Thind *et al.,* (2008) where high yield was recorded under fertigation due to more N uptake, fertilizer N utilization efficiency compared to soil application.

Seed cotton yield in total ranged from 1731 kg ha^{-1} to 2919 kg ha^{-1} with mean of 2498 kg ha^{-1} and drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage once in 3 days recorded significantly higher yield (2919 kg ha^{-1}) than rest of the treatments except drip irrigation at 0.8 Epan throughout life and fertigation of equal splits once in 3 days (2783 kg ha^{-1}), 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of differential dosage once in 3 days (2823 kg ha^{-1}) and 0.8 Epan throughout the life and fertigation of differential dosage once in 7 days (2806 kg ha^{-1}) which were on par with former treatment (Table 1). There was no significant difference among fertigation of differential dosages once in 3 or 7 days or equal splits once in 3 days with drip irrigation at 0.8 Epan and drip irrigation at 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of equal or differential splits once in 3 days differential splits once in 7 days treatments. There was an increase of 4.9 per cent yield with 0.8 Epan throughout the life and fertigation of differential dosage once in 3 days over 0.8 Epan throughout life and fertigation of equal spilts once three days. This might be due to application of fertilizers based on growth stage results in availability of nutrients during crop growth period and maintaining adequate soil moisture in the root zone depth throughout the crop growth period which facilitated in better uptake of water and nutrients having beneficial effect on growth *viz.,* plant height which favoured more production and translocation of photosynthates to the sink resulted in more yield attributes and thereby resulted in higher seed cotton yield. Similar findings were also reported by Pawar *et al*. (2014) and Chauhan *et al*. (2014).

Significantly lower seed cotton yield was observed in conventional method furrow irrigation at IW/CPE ratio of 0.8 and application of RDF to soil (1731 kg ha^{-1}) over rest of the treatments except with 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of equal splits once in 7 days (1971 kg ha^{-1}). The seed cotton yield decrease observed was 40.7 per cent when compared to 0.8 Epan throughout life and fertigation of differential dosage once in 3 days and 38.7 per cent compared to 0.6 Epan up to flowering and 0.8 Epan later on and fertigation of differential dosage once in 3 days. Similar reports of lower yield under furrow irrigation compared to drip irrigation were reported by the Bhalerao *et al.* (2011).

Table 1. Yield attributes and yield of *Bt* cotton as influenced by different drip fertigation schedules and irrigation regimes

S. No	Treatments	Number of bolls plant^{-1}	Boll weight (g)	Seeds boll^{-1}	Seed index (g)	Seed cotton yield plant^{-1}(g)	Seed cotton yield (kg ha^{-1})
1.	Drip irrigation at 0.8 Epan throughout life (DI_1) - Fertigation of Equal splits (ES) once in 3 days	74.5	4.92	34.1	8.42	195.9	2783
2.	DI at 0.6 Epan upto flowering and 0.8 Epan later on (DI_2) – Fertigation of ES once in 3 days	70.7	4.41	33.0	7.53	180.8	2550
3.	DI_1 - Fertigation of ES once in 7 days	66.3	4.38	31.3	7.94	168.5	2362
4.	DI_2 - Fertigation of ES once in 7 days	62.2	4.41	30.3	7.55	143.1	1971
5.	DI_1 - Fertigation of differential dosage based on growth stage (DS) once in 3 days	84.2	5.00	36.3	8.60	204.7	2919
6.	DI_2 - Fertigation of DS once in 3 days	75.6	4.43	35.5	8.09	198.5	2823
7.	DI_1 - Fertigation of DS once in 7 days	73.9	4.48	35.4	8.23	197.4	2806
8.	DI_2 - Fertigation of DS once in 7 days	70.1	4.50	32.1	8.04	179.8	2535
9.	Conventional method furrow irrigation (IW/CPE = 0.8) with application of 100% RDF to soil	56.7	3.91	27.1	7.08	127.5	1731
	Mean	70.5	4.50	32.8	7.94	177.4	2498
	SEm ±	2.1	0.16	0.6	0.23	6.0	92
	CD (P= 0.05)	6.2	0.48	1.7	0.67	18.0	277
	CV (%)	5.1	6.11	3.0	4.91	5.9	6.4

Mean increase of 10.4 per cent seed cotton yield with drip irrigation at 0.8 Epan throughout life over 0.6 Epan up to flowering and 0.8 Epan later on. Similarly, a mean increase of 14.5 per cent in seed cotton yield fertigation once in 3 days over 7 days and 14.7 per cent increased yield with fertigation of differential dosage over equal splits. Significantly, there was a mean increase of 68.6 per cent and 60.7 per cent seed cotton yield with drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage or equal splits, respectively once in 3 days over furrow irrigation. Similar results were reported by Sahadeva Reddy and Aruna (2010). Application of RDF in more number of splits was more beneficial under drip irrigation than recommended method of manual fertilizer application. Similar results were also reported by Tumbare *et al*., (1999) who found that higher yield of seed cotton with more splits was the result of efficient utilization of applied nitrogen and potassium through fertigation than band placement.

The present investigation revealed that drip irrigation at 0.8 Epan throughout life and fertigation of differential dosage once in 3 days recorded significantly higher yield among different treatments to *kharif* cotton.

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Research Notes
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DEVELOPMENT AND EVALUATION OF RICE BRAN ENRICHED READY TO COOK EXTRUDATES

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In this era of global industrialization and advancement of technologies, the demand for ready to eat foods like extruded foods has increased and these are rich in starch, fat and energy but depleted in fiber leading to gastrointestinal and cardiovascular diseases (Grewal, 2007). The food processing industry produces large quantities of waste products (Chauhan and Intelli, 2015).

Extrusion is a versatile, continuous process and uniquely combines different processing steps, such as mixing of different components, degassing, thermal and mechanical heating, forming and expanding (Steiger *et al.,* 2014). Cold extrusion takes place at temperatures above glass transition but below starch melting temperatures, while the melting temperature of starch is exceeded in hot extrusion. The cold extrusion temperature and moisture conditions allow no melting of amylopectin and warm extrusion allows a limited melting, while amylopectin is melted to a large extent during hot extrusion (Steiger *et al.,* 2014).

Rice bran stabilization was carried out in microwave oven by heating at 120°C for 3 min followed by cooling at room temperature overnight to ensure complete inactivation of endogenous lipase enzyme (Malekian *et al.,* 2000).

The polished MTU 1001 rice variety was soaked in water, drained, sun dried, milled to fine powder and sieved to a particle size of 2.00 mm and packed in an air tight container till further usage.

Cold extrudates were prepared by moistening composite flour (consisting of rice flour and refined wheat flour in the ratio of 40:60, 50:50 and 60:40) through continuous kneading to desired crumbly consistency similar to moist breads. Sheeting of dough was made by a process of folding and passing through rollers of noodle machine several times. Sheeted dough was extruded through a suitable dye, cut to desired size of extrudate and shade dried. The cold extrudates were steamed for 20 minutes at 102-105 °C and dried at 60 °C in a tray drier. The composite flour with a combination of 40:60 ratio of rice and refined wheat flour was the best accepted by semi trained panelists (15 No. s) using '9' point hedonic scale.

The best accepted composite flour with a combination of 40:60 ratio of rice and refined wheat flour was added with stabilized rice bran at 4 different levels *viz.* 5%, 10%, 15% and 20%. Sensory analysis of cold extrudates prepared by manual method with rice flour, refined wheat flour and stabilized rice bran were evaluated by fifteen semi-trained panelists at Post Graduate & Research Centre, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad using 9 point hedonic scale and extrudates were scored for colour, texture, flavour, taste and overall acceptability. Scores were based on a hedonic rating of 1 to 9 where: 1 is "I dislike extremely" (very bad) and 9 is "I like extremely" (excellent) as given by Meilgaard *et al.,* (1999).

The cold extrudates prepared using refined wheat and rice flours in the ratio of 40:60, 50:50 and 60:40 were evaluated for sensory qualities like colour, texture, taste, flavor and overall acceptability. The sensory scores for colour ranged from 6.60 to 7.40, texture 6.47 to 8.27, taste 6.40 to 7.67, flavor 6.47 to 7.93 and overall acceptability from 6.47 to 7.53 for the three extrudates when incorporated with rice flour at 40, 50 and 60% levels. The sensory evaluation results were given in the Table 1.

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Table 1. Mean sensory scores of control extrudates

Extrudate	Colour	Texture	Taste	Flavor	Overall acceptability
C_1	7.40^b±0.51	8.27^a±0.46	7.67^a±0.49	6.47^c±0.52	7.53^a±0.52
C_2	7.93^a±0.70	7.47^b±0.52	7.27^b±0.46	7.47^b±0.52	7.00^b±0.54
C_3	6.60^c±0.51	6.47^c±0.52	6.40^c±0.51	7.93^a±0.70	6.47^c±0.52
CD	0.443	0.353	0.385	0.428	0.403
S.E	0.2163	0.1726	0.1880	0.2088	0.1968

Note: Values are expressed as mean ± standard deviation of three determinations

Means within the same column followed by a common letter are not significantly different at $p \leq 0.05$

C_1: 40% rice flour and 60% refined wheat flour

C_2: 50% rice flour and 50% refined wheat flour

C_3: 60% rice flour and 40% refined wheat flour

The results showed significant difference ($p < 0.05$) in the colour when added with rice refined flour between 40 to 60%. The colour of extrudate with 50% rice flour was rated high in comparison to 40 and 60% rice flour addition. The least score was for colour for extrudate made with 60% rice flour. There was a significant decrease ($p < 0.05$) in the colour of extrudate with 40% rice flour of all three extrudates. Textural properties also showed significant difference between the three extrudates. The extrudate with 60% rice flour had better texture than the other two extrudates.

Similarly, the flavour and overall acceptability of extrudates made with 40% rice flour had the highest rating than the remaining two samples in the hedonic scoring and the extrudates differed significantly ($p < 0.05$). Among the three extrudates the one with 40% rice flour and 60% refined wheat flour was rated the best. The extrudate was used as the control to proceed further with value addition in the investigation.

The control with 40% rice flour and 60% refined wheat flour was added with stabilized rice bran at 5, 10, 15 and 20% to develop the extrudates labeled as CRB_1, CRB_2, CRB_3 and CRB_4. The results of sensory evaluation of cold extrudates developed with (CRB) extrudates are given in the Table 2.

Table 2. Mean sensory scores of stabilized rice bran incorporated extrudates

Extrudate	Colour	Texture	Taste	Flavor	Overall acceptability
Control	7.40^{ab}±0.50	8.27^a±0.46	7.67^a±0.49	6.47^c±0.52	7.53^a±0.52
CRB_1	7.67^a±0.81	7.00^c±1.13	7.07^a±1.16	6.47^c±0.52	6.47^b±0.52
CRB_2	7.47^{ab}±0.64	7.47^{bc}±0.52	7.33^a±0.49	7.47^b±0.52	6.60^b±0.51
CRB_3	7.07^b±0.79	8.00^{ab}±0.93	7.67^a±0.49	7.93^a±0.70	7.47^a±0.52
CRB_4	7.00^b±0.75	7.33^c±0.47	7.20^a±0.86	7.27^b±0.46	6.67^b±0.72
SE	0.260	0.282	0.259	0.171	0.182
CD	0.523	0.565	0.520	0.343	0.365

Note: Values are expressed as mean ± standard deviation of three determinations.

Means within the same column followed by a common letter are not significantly different at $p \leq 0.05$

CRB_1: 5% rice bran incorporated extrudate

CRB_2: 10% rice bran incorporated extrudate

CRB_3: 15% rice bran incorporated extrudate

CRB_4: 20% rice bran incorporated extrudate

The colour of wheat and rice flour extrudates incorporated with stabilized rice bran ranged from 7.00 - 7.67, texture from 7.33 - 8.27, taste 7.20 - 7.67, flavour 6.47 - 7.93 and overall acceptability from 6.47 - 7.53. The colour and taste of control and value added extrudates were found to be more or less similar. Texture is one of the most important properties of food stuff and includes roughness, smoothness and graininess. There was no significant difference between the texture of control and rice bran added extrudates. Among the tested extruded formulations incorporating stabilized rice bran, flavour improved and extrudate with 15% stabilized rice bran incorporation had the best flavour followed by 10, 20 and 5% extrudates. The overall acceptability was high in control extrudate followed by 15% incorporated extrudate and least was for 5% incorporated extrudate.

The sensory scores of control extrudate with rice flour + refined wheat flour and stabilized rice bran incorporated control extrudate were evaluated for the sensory parameters *viz.* colour, texture, taste, flavour and overall acceptability. The extrudates with rice flour to refined wheat flour in the ratio of 40:60 was selected to which stabilized rice bran added at 15% was found to be the best. The study concluded that the increase in levels of stabilized rice bran decreased the sensory acceptability but improved *in-vitro* starch and dietary fiber content.

From the present studies, it is therefore concluded that incorporation of rice bran at 15% extrudates with rice flour and refined wheat flour not only improves the texture, taste and overall acceptability but also the nutritive value of the extrudates which are generally thrown away can be utilized in a better way thus reducing wastage.

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Research Notes
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COST AND RETURNS OF PREDOMINANT INTEGRATED FARMING SYSTEMS ADOPTED BY SMALL AND MARGINAL FARMERS IN ADILABAD DISTRICT, TELANGANA

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An integrated farming system (IFS) is one which focuses on judicious combinations of any one or more of such enterprises and effective recycling of crop residues and wastes for better management of available resources with small and marginal farmers to generate more income and employment for family labourers during off seasons. The decrease in operational land holding, increasing rate of population and declining rate of per capita availability of cultivated land have been major concerns to our nation since the scope for horizontal expansion in farming is limited. Vertical expansion is possible only through adoption of the latest technology, bio-engineering and changing of cropping methods to integration of farming systems by putting the components systematically and scientifically in the right order, consuming the least space.

Adilabad district, nearly 47% of the landholdings belong to the marginal farmers group i.e., those owning less than 1ha land, but the share of marginal farmers in the total land owned is only 13%. Small farmers have one fourth share in the total number of land holdings. They own 22% of the agricultural land in the district. Under these circumstances, it was felt that there is need for an analysis of existing farming systems and suggest a suitable one for small and marginal farmers for augumenting their farm income throughout the year.

In order to workout the cost and returns of predominant farming systems adopted by small and marginal farmers in Adilabad district, a total of 120 farmers (60 each of small and marginal farms) from 10 selected villages of five identified mandals of Adilabad district were purposively selected by adopting random sampling technique. The data required was obtained from both primary and secondary sources. The primary data were obtained from the selected sample farmers by interview method through a pre-tested questionnaire. About 21 farming systems were adopted by the related small and marginal farmers of which total 13 farming systems were adopted by small farmers and among them six farming systems were identified as predominant based on the percentage of adoption and the economics which was worked out using simple budgeting technique.

Component wise per farm cost and returns of the predominant farming systems adopted by small farmers

The economics and profitability of the six major farming systems adopted by small farms along with their component wise acreage / number were presented in Table 1.

In farming system I (Paddy+ Dairy+ Moriculture) of small farms, the gross return was highest for dairy Rs. 38825 followed by moriculture Rs. 38725 and paddy Rs. 35840. The component wise total cost was Rs. 24717.6, Rs.24060 and Rs. 22177.3 for moriculture, paddy and dairy, respectively. The net returns were of Rs. 16647.7, Rs. 14007.4, Rs. 11780 respectively for dairy, moriculture and paddy. The return per rupee spent was highest for dairy (1.75) followed by moriculture (1.56) and paddy (1.48). The return per rupee spent for the total system was 1.59. These results are in conformity with the results reported by Ahmed Tanver (2006) that the dairy as a component of farming system recorded highest net returns in Mandya.

In farming system II (Paddy + Sericulture + Poultry) the component wise total cost was Rs. 43329.4, Rs. 26764 and Rs. 8104.4 for sericulture,

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paddy and poultry. The gross returns were highest for sericulture Rs. 98556.2, followed by paddy Rs. 39396 and poultry Rs. 9574. The net returns were of Rs. 55226.8, Rs. 12632 and Rs. 1469.6 respectively for sericulture, paddy and poultry. The return per rupee spent was highest for sericulture (2.27) followed by paddy (1.47) and poultry (1.18). The return per rupee spent for the total system was 1.88.

In farming system III (Paddy-Paddy-Tomato+Goat+Poultry), the gross return was highest for tomato Rs. 120300, followed by *kharif* paddy Rs. 98400, rabi paddy Rs. 85158.3, goat Rs. 24083.3, and poultry Rs. 10958.3. The component wise total cost was Rs. 61336.4, Rs. 59241.8, Rs. 52300, Rs. 12325.7 and Rs. 4916.3 for tomato, rabi paddy, kharif paddy, goat and poultry, respectively. The net returns were of Rs. 58963.6, Rs. 46100, Rs. 25916.5, Rs. 11757.6, Rs. 6042 respectively for tomato, kharif paddy, rabi paddy, goat and poultry. The return per rupee spent was highest for poultry (2.22) followed by tomato (1.96) and goat (1.95). The return per rupee spent for the total system was 1.78.

In farming system IV (Paddy-Paddy-Tomato+Cotton+Goat+Poultry), the component wise total cost was Rs. 47107.2, Rs. 45576.8, Rs. 41828.4, Rs. 41725.6, Rs. 12948.3 and Rs. 4442.1 for rabi paddy, tomato, *kharif* paddy, cotton, goat and poultry respectively. The gross return was highest for tomato Rs. 100500, followed by *kharif* paddy Rs. 75825, *rabi* paddy Rs. 66975, cotton Rs. 53200, goat Rs. 23250 and poultry Rs. 8591.6. The net returns were of Rs. 53392.8, Rs. 33996.5, Rs. 21398.2, Rs. 11474.4, Rs. 10301.7, Rs. 4149.5 respectively for tomato, *kharif* paddy, *rabi* paddy, cotton, goat and poultry. The return per rupee spent was highest for tomato (2.13) followed by poultry (1.93) and *kharif* paddy (1.81). The return per rupee spent for the total system was 1.70.

In farming system V (Paddy-Paddy-Brinjal+Dairy+Goat), the gross return was highest for brinjal Rs. 145650, followed by *kharif* paddy Rs. 102420, *rabi* paddy Rs. 89302.5, dairy Rs. 21300, and goat Rs. 9260. The component wise total cost was Rs. 67831.3, Rs. 67238.7, Rs. 59101.2, Rs. 19285.8 and Rs. 8120.3 for brinjal, *rabi* paddy, *kharif* paddy, dairy and goat, respectively. The net returns were of Rs. 77818.7, Rs. 43318.8, Rs. 22063.8, Rs. 2014.2, Rs. 1139.7 respectively for brinjal, *kharif* paddy, *rabi* paddy, dairy and goat. The return per rupee spent was highest for brinjal (2.15) followed by *kharif* paddy (1.73) and *rabi* paddy (1.33). The return per rupee spent for the total system was 1.70. These results are in conformity with the results reported by Saikumar (2005) that the vegetable component in the farming system under tank command area was highly profitable.

In farming system VI (Paddy-Paddy-Okra+Cotton+Dairy+Poultry), the component wise total cost was Rs. 47728.3, Rs. 47658.7, Rs. 43860.3, Rs. 39118.3, Rs. 11312.5 and Rs. 2228 for *rabi* paddy, okra, *kharif* paddy, cotton, dairy and poultry, respectively. The gross return was highest for okra Rs. 83400, followed by *kharif* paddy Rs. 83000, *rabi* paddy Rs. 71852, cotton Rs. 48720, dairy Rs. 18900 and poultry Rs. 6190. The net returns were of Rs. 39139.6, Rs. 35741.4, Rs. 24123.7, Rs. 9601.7, Rs. 7587.5 and Rs. 3962 respectively for *kharif* paddy, okra, *rabi* paddy, cotton, dairy and poultry. The return per rupee spent was highest for poultry (2.77) followed by paddy (1.89) and okra (1.75). The return per rupee spent for the total system was 1.63.

Component wise per farm cost and returns of predominant farming systems adopted by marginal farmers

About 17 farming systems were identified on marginal farms, among which five major farming systems based on high percent of adoption by marginal farmers were considered as predominant ones. The economics and profitability of those major five farming systems along with individual components and their acreage/number are presented in Table 2.

In farming system I (Paddy+Dairy + Moriculture), the gross return was highest for moriculture Rs. 23043.7, followed by dairy Rs. 22175 and paddy Rs. 16380.4. The component wise total cost was Rs. 13920.7, Rs. 11114.8 and Rs. 10779.0 for moriculture, paddy and dairy, respectively. The net returns were of Rs.11396, Rs. 9122.0, Rs. 5265.6 respectively for dairy, moriculture and paddy. The return per rupee spent was highest for dairy (2.05) followed by moriculture (1.65) and paddy (1.47). The return per rupee spent for the total system was 1.72.

In farming system II (Paddy+Sericulture+ Poultry), of marginal farms, the component wise total cost was Rs. 17511.8, Rs. 9871 and Rs. 2845.4 for sericulture paddy and poultry. The gross return was highest for sericulture Rs. 36770.8, followed by paddy Rs. 14711 and poultry Rs. 5725. The net returns were of Rs. 19259 Rs. 4840 and Rs. 2879.6 respectively for sericulture, paddy and poultry. The return per rupee spent was highest for sericulture (2.09) followed by poultry (2.01) and paddy (1.49). The return per rupee spent for the total system was 1.89.

In farming system III (Paddy-Brinjal+Cotton +Goat), the gross return was highest for cotton Rs. 39900, followed by brinjal Rs. 28800, paddy Rs. 20960 and goat Rs. 10500. The component wise total cost was Rs. 26766.7, Rs. 15382.6, 13188 and Rs. 7904.3 for cotton, brinjal, paddy and goat, respectively. The net returns were of Rs. 13417.4, Rs. 13133.3, Rs. 7772.0, Rs. 2595.7 respectively for brinjal, cotton, paddy and goat. The return per rupee spent was highest for brinjal (1.87) followed by paddy (1.59) and cotton (1.49). The return per rupee spent for the total system was 1.58.

In farming system IV (Paddy-Okra+Cotton+ Dairy+Poultry), the component wise total cost was Rs. 26070.2, Rs. 17149.2, Rs. 14698.5, Rs. 13697.7 and Rs. 2512.1 for cotton, dairy, okra, paddy and poultry respectively. The gross return was highest for cotton Rs. 32340, followed by okra Rs.24150, dairy Rs. 23500, paddy Rs. 21440 and poultry Rs. 3600. The net returns were of Rs. 9451.5, Rs. 7742.3, Rs. 6350, Rs. 6269.8 and Rs. 1087.9 respectively for okra, paddy, dairy, cotton and poultry. The return per rupee spent was highest for okra (1.64) followed by paddy (1.57) and poultry (1.43). The return per rupee spent for the total system was 1.41. Ravishankar (2007) in his study on integrated farming system in Calicut also observed the highest net returns from crop component followed by the dairy.

In farming system V (Paddy-Tomato+Cotton +Goat+Poultry), the gross return was highest for cotton Rs. 40320, followed by tomato Rs. 33360, paddy Rs. 24325, goat Rs. 7860 and poultry Rs. 5160. The component wise total cost was Rs. 25623.1, Rs. 18069.2, Rs. 15782.3, Rs. 6523.4 and Rs. 2592.2 for cotton, tomato, paddy, goat and poultry respectively. The net returns were of Rs.15290.8, Rs. 14696.9, Rs. 8542.7, Rs. 1336.6 and Rs. 2567.8 respectively for tomato, cotton, paddy, poultry and goat. The return per rupee spent was highest for poultry (1.99) followed by tomato (1.85) and paddy (1.54). The return per rupee spent for the total system was 1.62. Chandel (2006) also reported highest returns per rupee spent on poultry component in farming systems adopted by different farm size groups in poor endovered regions of India.

Table 1. Component wise per farm cost and returns of predominant farming systems adopted by small farms

Component	Area (ha) /no.	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	Returns per rupee spent
FS I- (P+D+M)					
Paddy	0.36	24060.0	35840.0	11780.0	1.48
Dairy	9.41	22177.3	38825.0	16647.7	1.75
Moriculture	0.73	24717.6	38725.0	14007.4	1.56
Total		70954.9	113390.0	42435.1	1.59
FS II- (P+S+Po)					
Paddy	0.44	26764.0	39396.0	12632.0	1.47
Sericulture	1	43329.4	98556.2	55226.8	2.27
Poultry	7.8	8104.4	9574.0	1469.6	1.18
Total		78197.8	147526.2	69328.4	1.88

Component	Area (ha) /no.	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	Returns per rupee spent
FS III- (P-P-T+G+Po)					
Paddy *(Kharif)*	0.86	52300.0	98400.0	46100.0	1.88
Paddy *(Rabi)*	0.86	59241.8	85158.3	25916.51	1.43
Tomato	0.86	61336.4	120300.0	58963.6	1.96
Goat	9.66	12325.7	24083.3	11757.6	1.95
Poultry	8.33	4916.3	10958.3	6042.0	2.22
Total		190120.2	338899.9	148779.7	1.78
FS IV- (P-P-T+C+G+Po)					
Paddy *(Kharif)*	0.68	41828.4	75825.0	33996.5	1.81
Paddy *(Rabi)*	0.68	45576.8	66975.0	21398.2	1.47
Tomato	0.68	47107.2	100500	53392.8	2.13
Cotton	0.53	41725.6	53200	11474.4	1.27
Goat	9	12948.3	23250	10301.7	1.80
Poultry	8.16	4442.1	8591.6	4149.5	1.93
Total		193628.4	328341.6	134713.1	1.70
FS V- (P-P-B+D+G)					
Paddy *(Kharif)*	0.98	59101.2	102420.0	43318.8	1.73
Paddy *(Rabi)*	0.98	67238.7	89302.5	22063.8	1.33
Brinjal	0.98	67831.3	145650.0	77818.7	2.15
Dairy	9.6	19285.8	21300.0	2014.2	1.10
Goat	10	8120.3	9260.0	1139.7	1.14
Total		221577.3	3617932.5	146355.2	1.70
FS VI- (P-P-O+C+D+Po)					
Paddy *(Kharif)*	0.72	43860.3	83000.0	39139.6	1.89
Paddy *(Rabi)*	0.72	47728.3	71852.0	24123.7	1.51
Okra	0.72	47658.7	83400.0	35741.4	1.75
Cotton	0.48	39118.3	48720.0	9601.7	1.24
Dairy	10	11312.5	18900.0	7587.5	1.67
Poultry	10	2228.0	6190.0	3962.0	2.77
Total		191906.1	312062	120155.9	1.63

Table 2. Component wise per farm cost and returns of predominant farming systems adopted by marginal farms

Component	Area (ha) /no.	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	Returns per rupee spent
FS I- (P+D+M)					
Paddy	0.18	11114.8	16380.4	5265.6	1.47
Moriculture	0.45	13920.7	23043.7	9122.0	1.65
Dairy	6.3	10779.0	22175.0	11396.0	2.05
Total		46486.1	77979.6	31493.5	1.72
FS II- (P+S+Po)					
Paddy	0.16	9871.0	14711.0	4840.0	1.49
Sericulture	0.46	17511.8	36770.8	19259.0	2.09
Poultry	5.58	2845.4	5725.0	2879.6	2.01
Total		30228.2	57206.8	26978.6	1.89
FS III- (P-B+C+G)					
Paddy	0.22	13188.0	20960.0	7772.0	1.59
Brinjal	0.22	15382.6	28800.0	13417.4	1.87
Cotton	0.36	26766.7	39900.0	13133.3	1.49
Goat	3.4	7904.3	10500.0	2595.7	1.32
Total		63241.6	100160.0	36918.4	1.58
FS IV- (P-O+C+D+Po)					
Paddy	0.22	13697.7	21440.0	7742.3	1.57
Okra	0.22	14698.5	24150.0	9451.5	1.64
Cotton	0.36	26070.2	32340.0	6269.8	1.24
Dairy	4.6	17149.2	23500.0	6350.8	1.37
Poultry	5	2512.1	3600.0	1087.9	1.43
Total		101312.2	150620.0	49307.8	1.41
FS V- (P-T+C+G+Po)					
Paddy	0.26	15782.3	24325.0	8542.7	1.54
Tomato	0.26	18069.2	33360.0	15290.8	1.85
Cotton	0.34	25623.1	40320.0	14696.9	1.24
Goat	3	6523.4	7860.0	1336.6	1.20
Poultry	5.4	2592.2	5160.0	2567.8	1.99
Total		68590.2	111025.0	42434.8	1.62

Among the predominant integrated farming systems adopted by small and marginal farms, Paddy+Sericulture+Poultry, Paddy-Paddy+ Tomato+ Goat+Poultry, Paddy-Paddy+ Tomato+ Cotton+ Goat + Poultry and Paddy+Dairy+Moriculture were found to be yielding maximum returns as reflected by the values of highest return per rupee spent i.e., 1.89, 1.78, 1.70 and 1.72, respectively.

Of the different components indicated in different farming systems adopted by small and marginal farms, poultry followed by sericulture, vegetable crops and dairy were observed to be remunerative as indicated by the maximum value of the return per rupee spent for these enterprises.

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Research Notes
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INFLUENCE OF GLUTATHIONE SEED TREATMENT AND GAMMA IRRADIATION ON SEED GERMINATION OF REVALIDATED RICE VARIETY TELLAHAMSA UNDER AMBIENT STORAGE

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Tellahamsa is a popular variety in Telangana state particularly during *rabi* season because of its cold tolerance ability. It possesses good seedling and vegetative stage cold tolerance with short duration and long slender grain having excellent cooking and good keeping quality. Hence, this variety has become very popular in semi urban and rural areas of Telangana, where it is grown every year on continuous basis. However, in view of non availability of short duration, cold tolerant, fine grain variety with good cooking attributes, the demand for this variety will stay for some more time in near future. In this connection, earlier research work indicated that this variety tends to lose viability drastically after storage of one to two cropping seasons.

In view of this, it is very essential to develop cost effective, environment friendly seed storage protocol, for this very popular variety of Telangana. In many countries both fumigation with chemicals and heat sterilization have been applied with varying degree of success. However, such applications are ridden with disadvantages like toxic residue accumulation leading to potential environmental hazards and altering the storage potential of seed. Hence, gamma radiation administered at sub lethal doses can be availed as an effective alternative technology to sanitize the seed before storage and to minimize deterioration of seed quality and enhance storability. Gamma rays can also avoid recontamination and re-infection of irradiated seed due to high penetrating power in biological matrix. Further, Glutathione is a sulfhydryl antioxidant and acts as super oxide scavenger. Glutathione, when applied to seed before radiation treatment would counter act the stress during storage and aids in speedy recovery process of seed components and enhance better seed viability and seedling vigor. Since, this technology module is environmentally safe and poses minimum interference to seed quality; it holds promise and potential of up-scaling at commercial level.

The present study was carried out at MFPI-Quality Control Laboratory and Department of Seed Science and Technology, College of Agriculture, PJTSAU, Rajendranagar, during 2015-2016 which was laid out in Factorial CRD with three replications. Foundation seed of rice variety, Tellahamsa of 10 months old from Rice Research Center, ARI, Rajendranagar was used for the experimental purpose. Glutathione (reduced) was used for seed treatment. Glutathione solution was prepared with continuous agitation at 40^oC for 1 hour. Six litres of Glutathione solution @ 50, 100, 150 and 200 ppm was prepared by dissolving 50, 100, 150 and 200 mg of the chemical in 1000 ml of distilled water respectively. Seed was soaked in these solutions as per treatment for 3 hours and later shade dried. Gamma chamber 5000 was used for radiation treatments. It is a compact shelf shielded Co^{60} gamma irradiator with an irradiation volume of approximately 5000 cc. Seeds of Tellahamsa Rice variety weighing 400 g for each treatment was packed in HDPE bag (700 gauge) and exposed to 25, 50, 75 and 100 Gy doses of gamma radiation having 1.85 KGy hr^{-1} dose rate. Data on germination and speed of germination was generated at bimonthly intervals upto nine months of storage period.

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Interaction effects of Gamma doses and Glutathione concentrations presented in Table 1 suggested that germination percentage differed significantly during nine months of storage as elicited from bimonthly information. Among treatments, 25 Gy: Control, Glutathione 50 ppm; 50 Gy: Control, Glutathione 150 ppm and 100 Gy: Control registered significant higher percentage values of germination after 1st bimonthly studies and maintained the higher germination percentage upto 4th bi-month storage (82, 83, 82, 82 and 82%, respectively) and were significantly superior than corresponding values at 0 Gy gamma dose i.e., 62, 30, 62 respectively, than other treatments. Further, two treatments 25 Gy: Glutathione 150 ppm and 75 Gy: Control, though registered lower germination per cent of 78, 81 and 78, 76 at the end of 1st and 2nd bimonthly intervals respectively, but regained superiority in the second half of the storage period and registered above Minimum Seed Certification Standards of 82, 81 and 81, 80 respectively, after 3rd and 4th bimonthly intervals.

Several changes in the enzyme macromolecular structure may contribute to their lowered germination efficiency. Many hypotheses have also been proposed regarding causes of seed ageing such as lipid peroxidation mediated by free radicals, inactivation of enzymes or decrease in proteins, disintegration of cell membranes and genetic damage (McDonald, 1999, Murthy *et al.* 2003). Degradation and inactivation of enzymes due to changes in their macromolecular structures is one of the most important hypotheses proposed regarding causes of ageing in seeds (Bailly, 2004, Basavarajappa *et al.,* 1991, Goel *et al.,* 2002 Lehner *et al.,* 2008, McDonald, 2004). Most of these studies suggested that decrease in the activity of enzymes such as superoxide dismutase, catalase, peroxidase and glutathione reductase occurs in aged seeds. The general decrease in enzyme activity in the seed lowers the respiratory capacities, which in turn lowers both energy (ATP) and assimilate supply of the germinating seed.

Further, the data revealed that, germination per cent was significantly influenced by bimonthly interval of storage. After 1st bi-month of storage highest mean germination per cent of 77 was recorded which reduced to 49 per cent at the end of 4th bi-month period. Similar results by Ito *et al*. (1971), revealed that, rice irradiated with a dose of 0.1 Mrad extended the storage life from 2 to 3 months and at dose of 0.2 Mrad the storage life was extended for more than 3 to 4 months. The storage life of polyethylene packaged rice could be extended 3 to 4 times by means of 0.2 Mrad irradiation. By maintaining the moisture content of rice seed stored in polyethylene bag below 14.5 per cent a dose of 0.2 Mrad is probably enough to extend storage life safely more than a year.

Lin (1988) reported that, germination percentage decreased significantly with increasing length of storage. Loss of seed vigour paralleled the loss of seed germination. Loss of vigour was more rapid than loss of viability. Leakage of electrolytes was highly correlated with seed vigour and germination. Seed moisture content increased during storage, possibly indicating that membrane deterioration under high seed moisture content was involved in the loss of vigour and viability during storage.

Similarly, in the present study, gamma doses also exhibited profound influence on germination percentage, 25 Gy dose exhibited maximum mean germination percentage of 69, which was higher compared to other doses. Dose of 50 and 100 Gy recorded lower germination of 63 per cent. Glutathione was also found to have exercised significant influence on germination percentage. Maximum performance in germination was noticed in Control (80%) followed by Glutathione 150 ppm (77%). Lower germination per cent of 45 was observed in Glutathione 200 ppm. It is pertinent to note that prolonged storage generally reduces seed viability, though the rate of deterioration varies among species. Deterioration in aged seeds has long been associated with damage by oxidative reactions. These reactions include free radical oxidations, enzymic dehydrogenations, aldehyde oxidation and Maillard reaction (Murthy *et al.* 2003). Free radical oxidations may reflect the amount of lipid peroxidation, accumulation and the levels of glutathione in aged seeds. However, storage conditions and length greatly influenced the seed glutathione pool in the seed.

Speed of germination reflects the homogeneity of a seed lot in terms of its capacity to go through germination process efficiently. Speed of germination is an indirect indicator of seed viability and seed vigour. Estimates of speed of germination could be applied with reasonable accuracy to the seeds under the influence of natural ageing to predict the storability.

Similarly, speed of germination also ranged from 11.6 to 22.5 during 4th to 1st bimonthly intervals, respectively. During 1st bimonth interval the values were in the range of 19.9 to 26.6 and during 4th bimonth enhanced to 4.5 to 42.7. The treatments 25 Gy: Control (25.3), 25 Gy : Glutathione 150 ppm (25.6); 50 Gy : Control (26.2), 50 Gy : Glutathione 150 ppm (24.7) and 100 gy : Control (26.4) after 1st bi-month interval increased to 39.2, 38.9, 42.7, 39.6 and 39.3, respectively at the end of 4th bi-month storage. Apart from these treatments 25 Gy : Glutathione 150 ppm and 75 Gy: Control also registered significant superiority at the end of storage period. These treatments were significantly superior to remaining treatments during first and fourth bimonthly studies (Table 2).

Considering the storage period, lowest speed of germination (20.7) was recorded after 2nd bi-month and highest speed of germination was registered after 3rd bimonth of storage (26.5). Gamma doses also exercised significant influence on speed of germination. Highest speed of germination was recorded at 25 Gy (26.4) which was significantly superior over remaining doses followed by 75 Gy (24.0). Higher dose of 100 Gy recorded 23.2 which was also the lowest speed of germination recorded over all periods of storage. Further, Glutathione concentrations were significant for speed of germination at all the gamma doses during storage. Maximum speed of germination was recorded in Control (32.0) followed by Glutathione 150 ppm (30.7). Lowest speed of germination was recorded in Glutathione 200 ppm (15.2).

Perusal of results also indicated that speed of germination was positively associated with germination. At 0 Gy and 100 Gy speed of germination was marginally low due to lower germination levels which could be attributed to diminished metabolic activity and increased susceptibility to stress created by gamma irradiation and natural ageing (Rao, 1990) and higher speed of germination up to 75 Gy was presumably due to comparatively higher germination caused by stimulatory effect at lower gamma doses (Grabe, 1964).

Considering the results on germination parameters it could be concluded that revalidated seed of Tellahamsa variety exposed to different Gamma doses (25 to 75 Gy) and concentrations of Glutathione (50 and 150 ppm) could complete the process of germination in comparatively quick time than control and other treatment combinations, thus confirming the greater ability to buffer the effects of storage under the influence of gamma radiation. Finally, in this context it was observed that gamma dose of 25 Gy, 50 Gy, 75Gy and 100 Gy for Control and Glutathione 50 and 150 ppm were found to be most effective in sustaining the optimum seed germination during long term storage under the influence of gamma radiation.

Table 1. Germination (%) as influenced by the interaction among Gamma dose, Glutathione and Storage period

Gamma Dose	Influence of Gamma dose, Glutathione and Storage period																							
	1st Bi-month						2nd Bi-month						3rd Bi-month						4th Bi-month					
	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean
0 Gy	80 (63)	77 (61)	75 (60)	76 (61)	66 (54)	**75**	71 (57)	51 (46)	61 (51)	75 (60)	15 (23)	**55**	66 (54)	40 (39)	57 (49)	66 (54)	12 (20)	**48**	62 (52)	30 (33)	28 (32)	62 (52)	9 (17)	**38**
25 Gy	84 (66)	86 (68)	74 (59)	78 (62)	75 (60)	**79**	83 (66)	85 (67)	50 (45)	81 (64)	61 (51)	**72**	82 (65)	85 (67)	32 (34)	82 (65)	49 (44)	**66**	82 (65)	83 (65)	28 (32)	81 (64)	21 (27)	**59**
50 Gy	88 (69)	72 (58)	72 (58)	85 (67)	70 (57)	**77**	85 (67)	85 (48)	56 (48)	83 (65)	53 (47)	**72**	84 (67)	53 (47)	46 (43)	82 (65)	29 (33)	**59**	82 (65)	47 (43)	26 (31)	82 (65)	17 (24)	**51**
75Gy	78 (62)	76 (60)	77 (61)	76 (61)	77 (61)	**77**	76 (61)	71 (57)	44 (42)	78 (62)	71 (57)	**68**	81 (64)	61 (51)	34 (35)	78 (62)	49 (44)	**61**	80 (63)	53 (47)	16 (24)	74 (60)	27 (31)	**50**
100Gy	86 (68)	74 (59)	77 (61)	76 (60)	75 (60)	**78**	84 (66)	60 (51)	58 (50)	77 (61)	65 (54)	**69**	83 (66)	48 (44)	35 (36)	74 (60)	32 (34)	**54**	82 (65)	34 (36)	29 (33)	74 (60)	28 (32)	**49**
Mean	**83**	**77**	**75**	**78**	**73**	**77**	**80**	**70**	**54**	**79**	**53**	**67**	**79**	**57**	**41**	**76**	**34**	**58**	**78**	**49**	**25**	**75**	**20**	**49**
	Gamma Dose x storage period						Gamma Dose x Glutathione						Glutathione x storage period						Gamma Dose x Glutathione x storage Period					
SED ±	0.514						0.575						0.514						1.149					
CD (5%)	1.014						1.134						1.014						2.894					

Table 2. Speed of germination as influenced by the interaction among Gamma dose, Glutathione and storage period

Gamma Dose	Influence of Gamma dose, Glutathione and Storage period																							
	1st Bi-month						2nd Bi-month						3rd Bi-month						4th Bi-month					
	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean	Control	Glutathione 50 ppm	Glutathione 100 ppm	Glutathione 150 ppm	Glutathione 200 ppm	Mean
0 Gy	25.9	24.5	24.1	22.7	19.9	**23.4**	23.1	16.3	18.7	23.6	3.9	**17.1**	32.2	18.0	25.0	31.5	5.4	**22.4**	30.4	12.8	12.4	29.5	4.5	**17.9**
25 Gy	25.3	26.6	24.1	25.6	22.3	**24.8**	26.9	26.2	15.1	26.4	17.9	**22.5**	39.7	39.1	12.2	39.9	21.5	**30.5**	39.2	38.9	12.0	39.2	9.5	**27.8**
50 Gy	26.2	22.0	20.9	24.7	22.3	**23.2**	27.5	17.3	16.6	26.5	14.9	**20.6**	40.8	22.2	19.4	40.4	12.1	**27.0**	42.7	21.9	11.9	39.6	7.1	**24.6**
75Gy	24.9	23.2	22.3	23.8	23.4	**23.5**	24.8	22.7	13.2	25.7	21.2	**21.5**	39.7	27.4	13.8	38.0	19.4	**27.7**	38.2	24.8	6.9	35.6	11.2	**23.3**
100Gy	26.4	22.5	21.7	23.3	22.5	**23.3**	27.2	18.4	17.8	24.7	19.6	**21.5**	39.8	19.1	15.4	36.7	13.0	**24.8**	39.3	15.7	12.4	36.4	11.6	**23.1**
Mean	**25.7**	**23.8**	**22.6**	**24.0**	**22.1**	**23.6**	**25.9**	**20.2**	**16.3**	**25.4**	**15.5**	**20.6**	**38.4**	**25.2**	**17.2**	**37.3**	**14.3**	**26.5**	**38.0**	**22.8**	**11.1**	**36.1**	**8.8**	**23.3**
	Gamma Dose x storage period						Gamma Dose x Glutathione						Glutathione x storage period						Gamma Dose x Glutathione x storage Period					
SED ±	0.399						0.446						0.399						0.893					
CD (5%)	0.787						0.880						0.787						2.456					

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Research Notes
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EFFECT OF DRIP IRRIGATION AND NITROGEN FERTIGATION LEVELS ON YIELD AND WATER PRODUCTIVITY OF CABBAGE (*Brassica oleracea, L.*) UNDER POLYHOUSE CONDITIONS.

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A field experiment was conducted to study the effect of drip irrigation on yield and water productivity of cabbage under polyhouse conditions. Cabbage is an important and extensively grown vegetable crop under varied agro-climatic conditions. Cultivation of vegetables in polyhouse condition protects the crop against biotic (pests, diseases and weeds) and abiotic (temperature, humidity and light) stresses and ensures year round production of high quality vegetables like capsicum, cabbage etc especially during the off-season. Vegetable cultivation in polyhouse not only increases the productivity but also, enhances the quality of vegetables and it is being practiced in more than fifty countries all over the world.

Water is the most important component which plays vital role in agricultural production and it can restrict agricultural growth unless it is carefully conserved and managed. Sivanappan and Padmakumari (1980) compared drip and furrow irrigation systems and found that about one-third to one fifth of the normal quantity of water was sufficient for drip irrigated vegetable crops compared to those under surface irrigation, due to the direct application of water and nutrients in the vicinity of root zone and is suitable for versatile topographical and agro climatic conditions for various crops and soil. Considering the above facts and research need, the study is done to find effect of drip irrigation on cabbage production under polyhouse conditions.

The present investigation was conducted at the Horticultural garden, College of Agriculture, Rajendranagar, Hyderabad at latitude of 17°19' N, longitude of 78°24 ‘E and an altitude of 542.3 m above mean sea level, during *rabi* season of 2015-16 in Southern Telangana agro-climatic zone. The local climate is semiarid tropical with an average annual rainfall of 800 mm, of which about 66% was received during June to October. The present experiment was laid out in a Randomized Block Design, consists of 8 treatments *viz*., Polyhouse condition (PHC)+ drip Irrigation (DI), 0.75 Epan+100% N (T_1), Polyhouse condition+drip Irrigation, 0.75 Epan+125%N (T_2), Polyhouse condition+ drip Irrigation, 1.0 Epan +100% N (T_3), Polyhouse condition+ drip Irrigation, 1.0 Epan +125%N (T_4), Polyhouse condition+drip Irrigation, 1.25 Epan +100% N (T_5), Polyhouse condition + drip Irrigation, 1.25 Epan +125%N (T_6), Open field condition + drip Irrigation, 1.0 Epan +100% N (T_7), Open field condition+ drip Irrigation, 1.0 Epan +125%N (T_8) and replicated thrice. The recommended dose of fertilizer was 100-125-150 N, P_2O_5 and K_2O ha^{-1}, respectively. The plot size was 21.6 m^2 and 30 days old seedlings of cabbage (Indhu) were transplanted with a spacing of 60 x 45 cm.

A drip irrigation system was installed in the polyhouse with laterals of 16 mm diameter spaced at 0.4 m apart with spacing of 60 cm between inline emitters of 4 lph and control taps were fixed on all laterals in order to control the water flow in the system. Applied water quantified by flow meters to each individual treatment according to designated pan evaporation replenishment factor based on Class A open pan evaporimeter and the irrigation set time was calculated by the following relationship.

$$\text{Irrigation time (hours)} = \frac{\text{Pan evaporation rate (mm d}^{-1}\text{)}}{\text{Application rate (mm h}^{-1}\text{)}}$$

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$$\text{Application rate (mm h}^{-1}\text{)} = \frac{Q}{D_L \times D_E}$$

Where,

Q = Dripper discharge (l h^{-1})

D_L = Distance between lateral spacing (m) and

D_E = Distance between dripper (emitters) spacing (m)

Cabbage yield

The data presented in Table 1.1 indicated that among all the irrigation treatments the highest cabbage yield (18.83 t ha^{-1}) was obtained with PHC + DI at 1.0 Epan +125% N followed by 17.28 t ha^{-1} in PHC + DI at 1.0 Epan + 100% N (Table 1.1). Treatments T_5 and T_6 were statistically at par in increasing the yield of cabbage. The higher cabbage yield obtained at higher drip irrigation regimes were due to favorable soil moisture conditions in root zone depth which facilitated more vigorous and luxuriant vegetative growth, which in turn favoured better partitioning of assimilates from source to sink over rest of the irrigation scheduling treatments. The results are in agreement with the findings of Tanpure *et al.* (2007). While the lowest yield (10.34 t ha^{-1}) was observed with OFC + DI, PHC + (1.0 Epan)+ 100%N.

Perusal of the data on water productivity of cabbage reveals that drip irrigation scheduled at 0.75 Epan +125% N recorded highest water productivity (4.46 kg m^{-3}) closely followed by drip irrigation scheduled at 1.0 Epan + 125%N (4.21 kg m^{-3}). Though the curd yield was realized at higher level of drip irrigation i.e., 1.0 and 1.25 Epan, but the water productivity realized was less (3.87 and 2.37 kg m^{-3}) when compared to lower levels of drip irrigation schedules. With the Increase in irrigation level, the water productivity decreases gradually (Pillai *et al*., 1990).

Lower water productivity (2.11 kg m^{-3}) was observed with OFC at 1.0 Epan +100% N. Further, all the irrigation regimes under open field recorded comparatively lower water productivity (2.11 to 2.27 kg m^{-3}), compared to polyhouse drip irrigation treatments. The reason for lower water productivity might be due to the water stress experienced by the crop as evidenced by low leaf water content and high leaf water potential and also due to drastic reduction in the yield due to moisture stress in open field conditions. Similar results were reported by Parthasarathi *et al*. (2013) and Manal *et al*. (2007) in grain or fodder crop.

It can be concluded that cultivation of cabbage under polyhouse condition with drip irrigation scheduling at 1.0 Epan+125 % N resulted in highest yield than that cultivated in open field condition, due to efficient utilization of water and nutrients.

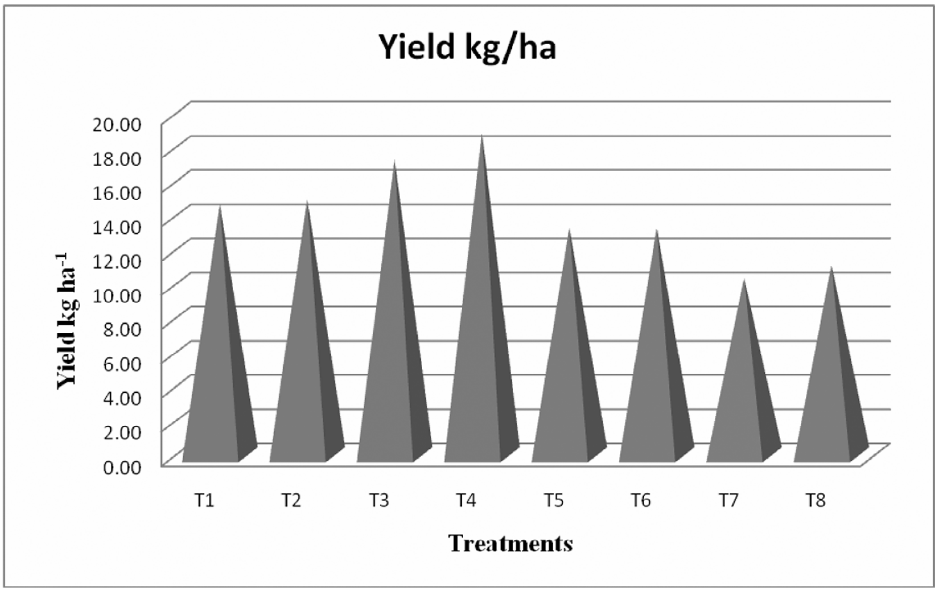

Fig 1.1 Yield (t ha^{-1}) of cabbage as influenced different irrigation regimes

Table 1.1. Cabbage yield (t ha^{-1}) and Water Productivity (kg ha^{-1} mm^{-3}) as influenced by different irrigation and N- Fertigation levels.

Treatments	Water applied (mm)	Yield (t ha^{-1})	Water productivity (kg ha^{-1} mm^{-3})
T1- PHC + drip Irrigation at0.75 Epan +100%N	334.9	14.66	4.37
T2- PHC + drip Irrigation at0.75 Epan +125%N	334.9	14.97	4.46
T3- PHC + drip Irrigation at1.0 Epan +100%N	446.5	17.28	3.87
T4- PHC + drip Irrigation at1.0 Epan +125%N	446.5	18.83	4.21
T5- PHC + drip Irrigation at1.25 Epan +100%N	558.13	13.27	2.37
T6- PHC + drip Irrigation at1.25 Epan +125%N	558.13	13.27	2.37
T7- OFC + drip Irrigation at1.0 Epan +100%N	446.5	10.34	2.11
T8- OFC + drip Irrigation at1.0 Epan+125%N	446.5	11.11	2.27
SEm±	28.12	0.60	0.35
CD (P=0.05)	85.31	1.82	1.07

(PHC- Polyhouse Condition, OFC- Open Field Condition)

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Research Notes
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In-vitro ANTIBACTERIAL ACTIVITY OF EXTRACTS OF BITTER GOURD WITH SELECTED MEDIA

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In recent years, there has been enormous interest in the development of anti-microbial agents from natural sources due to diseases caused by microbes which is on rampage causing large number of issues such as food poisoning, intestinal and extra intestinal infections, urinary tract infections, meningitis, peritonitis, mastitis, septicemia and gram-negative pneumonia. More recently, Multiple Drug Resistance (MDR) has developed due to indiscriminate use of commercial antimicrobial drugs commonly used in the treatment of such infectious diseases. Adding to this problem, antibiotics are sometimes associated with adverse effects on the host, including hypersensitivity, immune suppression and allergic response (Dey *et al.,* 2010).

Due to the side effects and the resistance that pathogenic microorganisms build against antibiotics as well as diseases arising from oxidative stress, intense attention has been paid to medicinal plants and biologically active compounds isolated from such plant species. Examples include naturally occurring foods such as bitter gourd, fenugreek seed, stevia which possess antimicrobial, antioxidant, along with nutraceutical properties like anti-diabetic/anti-hyperglycemic effects, lowering blood pressure and anti-inflammatory activity. The principal chemical constituents responsible for these effects are polyphenolic compounds (Gin and Rigalleau, 2000). One plant that has gained attention over the years for its medicinal properties is *Momordica charantia* commonly known as bitter gourd.

The plant belongs to Cucurbitaceae family and a common food item of the tropics and is used for the treatment of cancer, diabetes and many ailments (Modak *et al.*, 2007). The fruit and leaves contain alkaloids, glycoside, saponin like substances like rennin, an aromatic volatile oil mucilage. Bitter gourd and its leaves have been shown to exhibit various biological activities which include anti-diabetic, anti-rheumatic, anti-ulcer, anti-inflammatory and anti-tumor (Raman and Lau, 1996). However, the yield of the bioactive compounds and its consequent actions depends on the extraction media used as substantial liberation of the compounds largely correlates with the nature of the solvent or the media (Anjum *et al.,* 2013). The present study intends to prepare bitter gourd extracts in different media and to investigate the most effective solvent for extracting potent anti-microbial compound(s).

Dried bitter gourd powder mixed in 100 ml of water, ethanol and known concentrations of citric acid, sodium carbonate and sodium chloride solutions were subjected to extraction by cold maceration. Qualitative test for carbohydrates, proteins, amino acids, fixed oils and fats, terpenoids, steroids, phlobatanins and quinones were carried out according to the standard color test described by Harborne (1993). In disc diffusion method, a loop of bacteria from the agar slant stock was cultured in nutrient broth overnight and spread with a sterile cotton swab on petri plates containing 10 ml of nutrient agar medium. Sterile filter paper discs (9 mm in diameter) impregnated with the plant extract at different concentrations were placed on the cultured plates and incubated at 37 °C for 24 hrs. Standard antibiotic ampicillin was employed as a positive control. After 24 hrs of incubation, antibacterial activity was assessed by measuring the inhibition zone. The diameter of the zones of inhibition by the samples was then compared with the diameter of the zones of inhibition produced by the standard antibiotic discs. Each experiment was carried out in triplicate and the mean diameter of the inhibition ones was recorded. The test was carried out at a concentration of 100 µg/ml prepared from the bitter gourd in different media. All the data given are

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replicatesof three independent analysis and were subjected to analysis using Statistical package: Statistics 8.0. The data is reported as the mean ± SD and significant difference between mean values were determined with one way analysis of variance (RBD).

Qualitative phytochemical analysis of bitter gourd extracts was carried out for the detection of various constituents such as carbohydrates, proteins, amino acids, fixed oils and fats, terpenoids, steroids, phlobatanins and quinones. The result is presented in table 1.

Table 1. Peliminary phytochemical screening of Bitter gourd in different media

S. No.	Phytochemicals	Test	Na_2CO_3	Aqueous	Ethanol	NaCl	Citric Acid
1.	Carbohydrates	Molisch test	+	+	+	+	+
2.	Proteins	-	+	+	+	+	+
3.	Amino acids	Ninhydrin Test	+	+	+	+	+
4.	Fixed Oils and Fats	Foam Test	+	+	+	+	+
5.	Terpenoids	-	+	+	+	-	+
6.	Steroids	Liebermann -Burchard test	+	+	+	+	+
7.	Phlobatanins	With HCl	-	+	+	-	-
8.	Quinones	With HCl	-	-	-	-	-

The screening of the various extracts (ethanol, aqueous, Na_2CO_3, citric acid and NaCl) revealed the presence of phytochemical compounds. Ethanol was found to be the best extraction medium and extracts contained all the bio-actives analyzed. Phytochemicals which were tested positive included carbohydrates, proteins, amino acids, steroids, phlobatanins and terpenoids. The result obtained is similar to findings by Supraja and Usha, 2013, who reported the presence of these components in the fruits and leaves of *Momordica charantia*. The absence of quinones implies that the bioactive components did not undergo oxidation before the analysis.

The presence of these phytochemicals validates the reports that *Momordica charantia* can be of great pharmaceutical importance and are rich in wide variety of secondary metabolites. The notable therapeutic application includes; antimicrobial (tannins), antiviral, moluscidal and anti-tumoral activity and flavonoids possess anti-carcinogenic (flavonoids), antiviral, anti-hemorrhagic and antioxidant activity.

The antibacterial activity of bitter gourd extracts in various media was tested individually against three bacteria species *Staphylococcus aureus*, *Pseudomonas aerugenosa* and *Bacillus subtillis* using disc diffusion method. The result of the assay is presented in table 2.

Table 2. Antibacterial activity of bitter gourd extracts against selected bacteria species

Extracts	*Staphylococcus aureus* Zone of inhibition (mm)			*Pseudomonas aerogenosa* Zone of inhibition (mm)			*Bacillus subtilis* Zone of inhibition (mm)		
Ethanol	0.5± 0.01	2.0± 0.01	4.5± 0.09	1.1± 0.07	2.5 ± 0.0	3.6± 0.0	2.5± 0.05	3.5± 0.01	4.1± 0.08
Aqueous	0.3± 0.03	0.5±0.05	0.9± 0.02	0.2 ± 0.01	0.6±0.01	1.0± 0.06	0.5± 0.05	61.1 ± 0.02	1.3± 0.01
Citric acid	2.0± 0.01	3.5± 0.00	4.0± 0.03	0.2 ± 0.02	0.5± 0.01	0.9± 0.06	0.3± 0.01	1.5± 0.015	1.7± 0.01
Na_2CO_3	0.3± 0.04	0.6± 0.02	4.0± 0.01	0.6± 0.06	1.9± 0.00	2.0± 0.02	0.8± 0.09	1.3± 0.023	1.9± 0.00
NaCl	0.9± 0.03	1.1± 0.09	1.5± 0.00	0.3± 0.01	0.9± 0.05	1.0± 0.00	0.9± 0.08	1.3± 0.02	1.7± 0.04

Key: 1 – 10 ppm, 2 – 20 ppm, 3 – 30 ppm

The samples screened against *Staphylococcus aureus*, showed highest inhibition with a value of 4.5 mm with ethanol extract while the least zone of inhibition was found in aqueous extract (0.9 mm). Similarly, the result obtained for *Pseudomonas aerogenosa* indicated that ethanol extract was more effective antimicrobial agent (3.6 mm zone of inhibition) when compared to other crude extracts. The least inhibition was recorded for citric acid extract (0.9 mm zone of inhibition).

Furthermore, it was found that the maximum inhibition for ethanol extract (4.1 mm) and the least inhibition aqueous extract (1.3 mm) was observed for *Bacillus subtilis*. The present study complied with previous works which reported that all parts of the plant *Momordica charantia* have demonstrated active antibacterial activity (Kumar *et al.,* 2010). The potent antimicrobial efficacy of crude extract of ethanol implies that the solvent is a suitable media for substantial liberation of phytochemical constituents responsible for antimicrobial activity, but this higher activity can also be attributed to the polarized nature of active antimicrobials. The ethanol extract of bitter gourd may include alkaloids, glycosides, volatile oils or tannins (Taylor, 2002).

Previous studies had also demonstrated that *M. charantia* is very rich in triterpenes, proteins and steroids with isolated components including momordin, á and â - momorcharin, cucurbitacin B_1 and oleanolic acid (Oliff, 2007). The antimicrobial activity of triterpenes depends on interactions between the lipid components with the net surface charge of microbial membranes. The bio-actives can cross the cell membranes, penetrating into the interior of the cell and interacting with intracellular sites critical for antibacterial activity (Trombetta *et al.,* 2005). This probably is due to dilution effect or chemical antagonism of the various constituents on each other, resulting in inactive or less active products (Bourne and Roberts, 1984). Various researchers showed that gram positive bacteria are susceptible towards plant extracts than gram negative bacteria. These differences were attributed to the fact that the cell wall in gram positive bacteria is of a single layer, whereas the gram negative cell wall were multi-layered (Parekh and Chanda, 2007).

Flavonoids are responsible for antimicrobial activity of plants such as bitter gourd due to their ability to complex with extracellular and soluble proteins of bacterial cell walls. More lipophilic flavonoids may also disrupt microbial membranes. Terpenes and phenols from ethanol extract possess effective antimicrobial compounds (Sati and Joshi, 2011). The alkaloids and tannins have also been shown to enhance antimicrobial property of plant (Ruttoh *et al.,* 2009).

Although, the use of antibiotics has greatly reduced the incidence of infectious diseases, their extensive uses in therapy or as growth promoters in animal food has led to the appearance of drug-resistant bacteria which is a major public health issue worldwide. In order to inhibit food-borne pathogens and to extend shelf life of foods, synthetic chemicals are often used as preservatives in food processing and storage. The present study showed that ethanol extract of bitter gourd had highest antimicrobial activity among all other extracts tested and has potential for future applications in food systems to control microbial contaminations.

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PHOSPHORUS REQUIREMENT AND ITS TIME OF APPLICATION ON PERFORMANCE OF RICE GROWN ON P ACCUMULATED SOIL

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Crop utilization of applied fertilizer phosphorus is generally low due to sorption and precipitation reactions in soils. Consequently, a large accumulation of phosphorus takes place over the years, particularly in the soils that receive regular and liberal rates of P applied to each crop in a cropping system. The long-term fertilization experiments conducted across the country have clearly demonstrated the accumulation of phosphorus in the soils of different types, in spite of using recommended fertilizer doses (Nambiar, 1994). This is mainly because the applied P is usually fixed very quickly and is being retained in the top layers of the soil leading to slow and steady saturation of P-fixation sites in the soil. The residual P accumulated from previous additions can influence not only speciation and availability of P but also the availability of other nutrients. Under these circumstances, it is necessary to ascertain the requirement of P on such soil to crops not only to reduce the cost of chemical P fertilizer input from the current level of general recommendation but also to avoid any nutritional imbalances that might arise due to excess P availability (e.g. zinc).

The availability of P to rice grown on submerged soils depends on the dose of fertilizers and time of fertilizer application. The rice growing farmers in many regions applying P fertilizer in split doses through complex fertilizers perceive that plants require P throughout the crop growth period like nitrogen. However, according to many researches, application of P at the time of transplanting is the recommended practice for paddy. Moreover, farmers do not pay much attention on time of phosphorus fertilizers application resulting in low phosphorus use efficiency. But more often, due to various reasons, it is not always possible to apply the entire P at the time of transplanting as required. Under such circumstances, it is appropriate to know whether split applications of P or delayed application is permissible without any loss in yield, P use efficiency and its economy in these P accumulated soils. Keeping in view, the significance of optimum level and time of application for improving the soil phosphorus availability and yield of rice, it was planned to study the phosphorous requirement and its time of application to rice grown on P accumulated soil.

As part of this investigation, a survey was conducted in May, 2015 from 50 rice growing farmers from different villages of Nizamabad district to identify the way of farmers applying fertilizers including farmer's practice of dose and time of P application. Based on the survey data, treatments were decided for conducting field experiment on rice in P accumulated soil. Soil samples were collected from rice growing soils of Nizamabad district. A total of 50 soil samples were collected at the same geo-reference sites for characterizing soil nutrient status.

A field experiment was conducted during *kharif* 2015 with rice (*var*., BPT 5204) at Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad District, Telangana. As per title of experiment we have selected phosphorus accumulated soil for conducting field experiment on rice. The experimental site was sandy clay loam in texture. The soil was slightly alkaline in reaction and non-saline in nature. It was low in organic carbon and available nitrogen and high in available phosphorus and potassium. The experiment was laid out in Randomized Block Design with factorial concept consisting of twelve treatment combinations with six

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levels of phosphorus *viz*., P_1 (100% Farmers dose of P), P_2 (75% of Farmers dose of P), P_3 (50% of Farmers dose of P), P_4 (100% RDP), P_5 (75% RDP) and P_6 (50% RDP) and its time of application *viz*., T_1 (No. of splits as per farmers practice) and T_2 (Basal Application). A common dose of N and K_2O was applied to all the treatments. The details of the treatment combinations and amount of P fertilizers applied under different treatments are presented in Table 1.

phosphorus is about 25 kg P_2O_5 ha^{-1}, which is equal to 42%. These results are in conformity with the findings of Swamy and Rao (1995) who have reported that more than half of the farmers surveyed indicated that they were using increased rates of fertilizers inspite of higher costs of these materials.

This survey also revealed that, farmers are applying P fertilizer in split doses through complex fertilizers because they perceive that P is required throughout the crop growth period like nitrogen. However, according to many researches, application of P at the time of transplanting is the recommended practice for paddy. The survey indicated, majority of the rice growing farmers (44 %) in this area applying p fertilizers at basal and top dressing at early tillering stage. Whereas 26, 10, 10, 6 and 4 % of the farmers applying P fertilizers at basal, basal + mid tillering, basal+mid tillering + panicle initiation, basal + early tillering + panicle initiation and basal + panicle initiation stages, respectively.

Table 1. Phosphorus nutrient use under different treatments

Treatment	Total P_2O_5 applied (kg ha^{-1})		
	Basal	Top dressing	Total
P_1 T_1	42.50	42.50	85.00
P_1 T_2	85.00	-	85.00
P_2T_1	32.00	32.00	64.00
P_2T_2	64.00	-	64.00
P_3 T_1	21.25	21.25	42.50
P_3 T_2	42.50	-	42.50
P_4 T_1	30.00	30.00	60.00
P_4 T_2	60.00	-	60.00
P_5 T_1	22.50	22.50	45.00
P_5 T_2	45.00	-	45.00
P_6 T_1	15.00	15.00	30.00
P_6 T_2	30.00	-	30.00

Current Status of Fertilizer Use by Rice Growing Farmers

The fertilizer use trends in the surveyed region indicated that, the total (N, P_2O_5 and K_2O) fertilizer use by farmers was highest in all the villages, with an average of 131, 85 and 76 kg N, P_2O_5 and K_2O kg ha^{-1} (Table 2). The recommended NPK fertilizer application rate for rice is 120-60-40 kg N, P_2O_5 and K_2O ha^{-1}, respectively. Thus, application of NPK fertilizers is higher than crop demand. These results also indicated that application of phosphorus fertilizer by farmers was almost two times higher than the crop requirement. The difference in phosphorus application between farmers practice and recommended dose of

The average of 50 farmer's phosphorus fertilizer application dose *i.e.,* 85 kg P_2O_5 ha^{-1} was described as 100 % farmer's dose of P fertilizer

Table 2. Current status of fertilizer use by rice growing farmers in different villages of Nizamabad District

S.No.	Name of the Farmer	Name of the Village	Farmer Practice of NPK			Details of splits
			N	P_2O_5	K_2O	
1.	A. Pedda Ganga Reddy	Chepoor	116	80	78	Basal+ET
2.	V. Chinnaiah	Mamidipally	103	115	75	Basal
3.	V. Gangadhar	Chepur	88	80	78	Basal+ET
4.	S. Ashok	Pipri	133	75	75	Basal
5.	R. Raju	Manthani	132	115	75	Basal+ET
6.	N. Ganga Reddy	Degam	113	105	40	Basal+MT
7.	P. Srinivas	Machharla	142	60	38	Basal+PI
8.	G. Bajanna	Mamidipally	130	120	150	Basal+ET
9.	G. Gangaram	Padkal	128	75	78	Basal+ET
10.	G. Srinivas	Armoor	130	50	115	Basal+ET+PI
11.	M. Shivanna	Perkit	142	80	40	Basal+ET
12.	A. Linganna	Padkal	138	92	78	Basal+ET
13.	Y. Raja Reddy	Argul	135	75	78	Basal+MT+PI
14.	A. Srinivas	Aloor	142	105	38	Basal
15.	Ch. Chinnaiah	Anksapur	145	115	113	Basal+ET
16.	P. Ghanesh	Padkal	124	46	40	Basal+MT
17.	J .D. Jagadeesh	Chepur	112	105	40	Basal
18.	G. Satyam Reddy	Argul	142	115	78	Basal+ET
19.	S. Raja Reddy	Argul	126	112	38	Basal+ET
20.	T. Gangadhar Rao	Rudrur	118	68	40	Basal
21.	N. Srenivasa Rao	Varni	98	80	78	Basal+ET
22.	V. Rajendra Prasad	Sevalaltanda	108	88	113	Basal+ET
23.	D. Lingam	Boppapur	135	72	115	Basal+MT+PI
24.	S.K. Latif	Nasurullabad	132	75	78	Basal+MT+PI
25.	Kasiram	Bommandevpally	128	80	115	Basal
26.	S. Srikanth	Thimmapur	158	60	38	Basal+ET
27.	P. Potha Reddy	Nemli	145	62	78	Basal
28.	Hanma goud	Hunsa	126	80	112	Basal+ET
29.	Venkateswara Rao	Pantakurthi	118	58	72	Basal+ET
30.	Santhosh	Koyyagutta	145	68	78	Basal+MT
31.	Hanmandlu	Borlam	136	115	78	Basal
32.	Ravindra Babu	Venkatapur	142	75	40	Basal+ET+PI
33.	D. Bhrahmam	Deshaipet	142	80	38	Basal
34.	N. Balraj	Beerkur	136	128	40	Basal+ET
35.	N. Sailu	Kistapur	116	115	78	Basal+ET
36.	Arjun Rao	Ranampally	88	64	113	Basal+MT

Table 2. Current status of fertilizer use by rice growing farmers in different villages of Nizamabad District

S.No.	Name of the Farmer	Name of the Village	Farmer Practice of NPK			Details of splits
			N	P_2O_5	K_2O	
37.	A. Balaji	Suddulam	146	115	78	Basal
38.	S. Srinivas Yadav	Kotagiri	105	60	40	Basal+ET+PI
39.	Sudhakar Patel	Potangal	142	80	38	Basal+PI
40.	N. Gangadhar	Hangargav	138	80	78	Basal+MT+PI
41.	Ranga Babu	Karegam	152	75	78	Basal+ET
42.	Ch. Nagaiah	Jankampet	164	54	115	Basal
43.	P. Maruthi	Pocharam	162	115	115	Basal+ET
44.	Veeraju	Bapunagar	156	64	78	Basal
45.	D. Srinivas	Jamalam	126	105	38	Basal+ET
46.	Moulana	Oddepally	120	80	150	Basal+PI
47.	Murali	Brahmanapally	152	48	78	Basal
48.	Sudhakar Rao	Pitlam	146	115	113	Basal+ET
49.	Balaraju	Darmaram	132	75	38	Basal+MT+PI
50.	M. Raghupati Reddy	Burnapoor	135	80	115	Basal+ ET
	Average	**132**	**85**	**76**		

ET: Early Tillering MT: Maximum Tillering PI:Panicle Initiation

application for conducting field experiment on rice in P accumulated soil. With respect to time of P fertilizer application, majority of the farmer's practice two equal splits at basal and at top dressing at early tillering stage (14 to 20 DAT) was decided as per the objective laid out in the experiment.

Phosphorus Uptake

The P uptake of rice plant increased upto 90 DAT and then decreased at harvest. P uptake increased with increasing levels of phosphorus and its time of application at all the stages of crop growth except in straw at harvest, wherein P uptake was not significantly influenced by time of P application. Application of 100% farmers dose (P_1) recorded highest P uptake by rice plant at 30 (4.90 kg ha^{-1}), 60 (17.60 kg ha^{-1}), 90 DAT (22.57 kg ha^{-1}), grain (14.55 kg ha^{-1}) and straw (15.57 kg ha^{-1}) at harvest, respectively while the lowest was recorded in P_6 (Table 3). The favorable effect of higher availability of phosphorus in soil and different levels of P applied on dry matter production and content ultimately reflected in significant increase in P uptake by rice. Similar increase in P uptake by rice plant due to application of P was reported by Agarwal (1980), Babu *et al.* (2005) and Subbian *et al.* (1989).

With respect to time of P application, farmers practice of split application recorded highest P uptake at 30 (4.38 kg ha^{-1}), 60 (15.22 kg ha^{-1}), 90 DAT (20.58 kg ha^{-1}) and grain (13.11 kg ha^{-1}) at harvest and were significantly superior over basal application of P. The per cent increase being 19.6, 11.7, 16.87 and 14.80 at 30, 60, 90 DAT and grain at harvest, respectively over their corresponding basal application. The results also indicated that, P uptake by the grain was significantly higher in split application than the treatment receiving basal P, although this had no significant influence on the increase in straw uptake at harvest. P absorbed during the early tillering stage through top dressing is directly translocated to the grain and was adequate to improve the P uptake.

These observations along with yield data of rice in high P soil indicated that top dressing at early stages maintaining higher level of available P in soil helps in realization of maximum P uptake. Tandon (1987) opined that the modern high yielding varieties continue to absorb P till maturity and almost 70-80 %

Table 3. Effect of levels of phosphorous and its time of application on P uptake (kg ha^{-1}) by rice at different growth stages of rice

P Levels	30 DAT			60 DAT			90 DAT			Grain			Straw		
	T_1	T_2	Mean	T_1	T_2	Mean	T_1	T_2	Mean	T_1	T_2	Mean	T_1	T_2	Mean
P_1	5.43	4.36	**4.90**	17.83	17.36	**17.60**	24.80	20.33	**22.57**	15.12	13.58	**14.55**	15.96	15.58	**15.77**
P_2	4.79	4.25	**4.52**	17.34	14.83	**16.09**	22.28	19.81	**21.04**	15.68	12.95	**14.32**	13.66	13.49	**13.58**
P_3	3.23	2.78	**3.01**	12.30	11.00	**11.65**	15.65	13.87	**14.76**	10.08	8.60	**9.34**	10.56	10.32	**10.44**
P_4	5.07	4.16	**4.62**	16.28	14.59	**15.43**	22.19	19.49	**20.84**	14.60	13.04	**13.82**	16.79	14.35	**15.57**
P_5	4.68	3.79	**4.23**	15.17	13.38	**14.28**	21.87	18.33	**20.10**	13.22	11.23	**12.23**	16.18	14.83	**15.50**
P_6	3.09	2.63	**2.86**	12.40	10.58	**11.49**	16.70	13.82	**15.26**	9.57	9.13	**9.35**	10.99	11.20	**11.09**
Mean	4.38	3.66		15.22	13.62		20.58	17.61		13.11	11.42		14.02	13.29	
	S.Ed±		**CD (0.05)**	**S.Ed±**		**CD (0.05)**	**S.Ed±**		**CD (0.05)**	**S.Ed±**		**CD (0.05)**	**S.Ed±**		**CD (0.05)**
P	0.20		0.43	0.90		1.86	1.42		2.94	1.19		2.48	1.44		3.00
T	0.12		0.24	0.52		1.07	0.82		1.70	0.69		1.43	0.83		NS
PXT	0.29		NS	1.27		NS	2.01		NS	1.69		NS	2.03		NS

of the absorbed P ends up in the panicles and ear heads. The positive effect of split application at basal and maximum tillering stage on P uptake was reported by Ramaiah (1979). Sometimes delayed or split application of P is reflected in better P uptake rather than in higher yields, which was evident in the present study and is in agreement with the findings of Srujana (2013), Goswami and Kamath (1984) and Raju *et al*. (1983).

Grain and Straw Yield (t ha^{-1})

The results revealed that there was significant increase in rice grain and straw yield with application of different levels of phosphorus. However, time of application of phosphorus and their interaction effects were found to be non-significant. The mean grain yield of the crop was highest (6.41 t ha^{-1}) when 100 % farmers dose of P was supplied to the crop but at the same time it was found to be on par with the application of 100% RDP (6.38 t ha^{-1}), 75% farmers dose (6.37 t ha^{-1}) and 75% RDP (6.34 t ha^{-1}). Lower grain yield was recorded in 50% RDP (5.83 t ha^{-1}) which was significantly lower than the rest of the treatments (Table 4 & 5).

The data also indicate that, the yield level that could be achievable with 100 % farmers dose of P (85 kg P_2O_5 ha^{-1}) to P accumulated soil can be obtained with a lower dose of 75 % RDP (45 kg P_2O_5 ha^{-1}) supplied to the same crop and thus saving 40 kg of cost of P input in P accumulated soil. These observations point out that, there is a possibility of reducing the farmer's dose and recommended dose of P by 40 kg (48 % of farmer's dose) and 15 kg (25 % of RDP) P_2O_5 ha^{-1}, respectively without sacrificing the yield of rice crop grown on P accumulated soils. The results of this finding also corroborate earlier finding of (Kumar *et al*. 2015 and Meena *et al.* 2014). Higher yields associated with higher levels of P are obviously due to better root growth and increased uptake of nutrients favoring better crop growth.

With respect to time of P application, farmers practice of P *i.e.,* two equal splits at basal and top dressing at early tillering stage (14 to 20 DAT) along with first top dressing of N after the first weeding recorded highest grain and straw yield (6.27 and 7.55, t ha^{-1}, respectively) which was on par with complete P as basal application (6.21 and 7.51 t ha^{-1},

Table 4. Effect of levels of phosphorous and its time of application on grain yield (t ha^{-1}) of rice.

Fertilizer Phosphorus Levels (t ha^{-1})	Time of P Application		Mean
	T_1: Farmer No. of splits	T_2: Basal Application	
P_1: 100 %Farmer dose (85 kg P_2O_5 ha^{-1})	6.43	6.39	6.41
P_2: 75 % of Farmers dose (63 kg P_2O_5 ha^{-1})	6.42	6.32	6.37
P_3: 50% of Farmers dose (42 kg P_2O_5 ha^{-1})	6.11	6.06	6.08
P_4: 100% RDP (60 kg P_2O_5 ha^{-1})	6.41	6.35	6.38
P_5: 75% RDP (45 kg P_2O_5 ha^{-1})	6.37	6.31	6.34
P_6: 50% RDP (30 kg P_2O_5 ha^{-1})	5.85	5.81	5.83
Mean	6.27	6.21	
	S.Ed±	**CD (0.05)**	
P	0.08	0.17	
T	0.05	N.S.	
PXT	0.11	N.S.	

Note: Farmer No. of Splits**:** 50 % Basal + 50 % at Early Tillering Stage

Table 5. Effect of levels of phosphorous and its time of application on straw yield (t ha^{-1}) of rice.

Fertilizer Phosphorus Levels (t ha^{-1})	Time of P Application		Mean
	T_1: Farmer No. of splits	T_2: Basal Application	
P_1: 100 %Farmer dose (85 kg P_2O_5 ha^{-1})	7.70	7.65	7.67
P_2: 75 % of Farmers dose (63 kg P_2O_5 ha^{-1})	7.69	7.59	7.64
P_3: 50% of Farmers dose (42 kg P_2O_5 ha^{-1})	7.33	7.33	7.33
P_4: 100% RDP (60 kg P_2O_5 ha^{-1})	7.68	7.62	7.65
P_5: 75% RDP (45 kg P_2O_5 ha^{-1})	7.61	7.59	7.60
P_6: 50% RDP (30 kg P_2O_5 ha^{-1})	7.30	7.27	7.28
Mean	7.55	7.51	

	S.Ed±	CD (0.05)
P	0.06	0.13
T	0.03	N.S.
PXT	0.08	N.S.

respectively). Based on the results, it can be inferred that, P is more absorbed in first 20 DAT for root growth and penetration. The P absorbed during the early tillering stage of long duration rice var. BPT 5204 was more efficiently utilized for grain production. The results revealed that, soil having high P supplying capacity top dressing may be done without decrease in yield. This positive relationship of two splits of P was reported by Rao *et al.* (1973) at basal and 21 DAT, Ramaiah (1979) at basal and top dressing at 30 DAT and Budhar (1992) at basal and tillering stage. Similar positive results in three splits of P were reported by Singh *et al.* (1988) and Yadav *et al.* (2004) and four splits of P were reported by Thakur (1993). Non significant differences in grain yield due to split application were also reported by Balasubramanian *et al.* (1982), Sahu and Sahoo (1969) and Reddy *et al.,* (1984). The interaction levels of P with its time of application found to be non significant.

The results on grain yield concluded that, there is a possibility of saving of P fertilizers from current recommended dose and farmer's dose without sacrificing the yield of rice crop grown on P accumulated soils. Hence, the application of 75 % RDP may be recommended for rice grown in P accumulated soil under Nizamabad condition. With respect to time of P application, the split application also be followed successfully in rice crop without any adverse effect on grain yield of rice grown in P accumulated soil.

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