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GENETIC BEHAVIOUR OF BACTERIAL WILT RESISTANCE IN F₂ POPULATION OF BRINJAL (*Solanum melongena* L.)

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ABSTRACT

Brinjal or eggplant (*Solanum melongena* L.) is severely affected by bacterial wilt caused by *Ralstonia solanacearum* in Konkan Region of Maharashtra. Resistant varieties are most suitable option to reduce crop losses from bacterial wilt. The knowledge of resistance mechanism and its inheritance is important to develop resistant varieties. Thus, the present study was conducted during *rabi* 2015-16 to understand the genetic behaviour of bacterial wilt resistance in brinjal. For this study, the five F₂ population which were chosen by 15 F₁ hybrids derived from line x tester crosses of three female x five male parents. The experiment was carried out in naturally bacterial wilt affected plot available at Research Farm, Department of Agricultural Botany, College of Agriculture, Dapoli. It could be inferred that the inheritance of bacterial wilt resistance in brinjal plants under condition of naturally bacterial wilt infested soil was quantitative (polygenic) in nature.

INTRODUCTION

The brinjal or eggplant or aubergine (*Solanum melongena* L.) represents the non-tuberous group of *Solanum* species. Brinjal is the most common, popular and widely grown vegetable crop of both tropics and subtropics of the world. Brinjal usually finds its place as the poor man's vegetable (Som and Maity, 2002). Except in higher altitudes, it can be grown in almost all parts of India, all the year round. Large number of cultivars is grown throughout the country depending upon the consumer's preference for the colour, size, shape and the yield are specific which changes with region. In India, immature fruits of brinjal are consumed as cooked vegetable in various ways. Growth and productivity of brinjal plant is hampered by serious diseases like bacterial wilt (BW).

Recently, this disease rose to alarming proportion in the plains of India and has become one of the limiting factors. The bacterial wilt is caused by *Ralstonia solanacearum* (Smith). Yabuchi *et al.* (1995) reported that it causes yield loss ranging from 4.24 to 86.14 per cent. The race I of *Ralstonia solanacearum* infects almost all solanaceous crops. Source of resistance to bacterial wilt has been reported by many workers *viz.*, SM132, SM6-2, SM6-6, SM6-7 (Geetha and Peter, 1993), IHR-171, IHR-

180, IHR-181, IHR- 182, IHR-85 (Sadashiva *et al.*, 1994), Arka Nidhi, Arka Keshav, Arka Neelkantha, BB1, BB44, BB49, EP143, Surya, BB 13-1, BB2, Kerala local, SM6-6 (Ponnuswami, 1999). The wild brinjal *S. melongena* var. *insanum* (Srinivasan and Gopimony, 1969) and *Solanum torvum* SW (Gousset *et al.*, 2005) are resistant against *R. solanacearum*, but till today resistance to bacterial wilt in many local germplasms is not known.

At present, most of the commercially grown varieties of brinjal are susceptible to bacterial wilt which is a limiting factor for successful cultivation of this crop in the areas having high temperature and humidity during rainy season. Sometimes, there is a complete failure of crop, thereby resulting in huge economic losses to the vegetable growers. The chemical control of the disease involves huge expenditure and cumbersome too. The knowledge on genetics of resistance helps in the formulation of the breeding method. Therefore, development of resistant varieties suitable for Konkan region is most economic, eco-friendly and feasible method to ensure better productivity of brinjal. Therefore, the present study was undertaken to understand the genetic behaviour of bacterial wilt of brinjal in Konkan conditions.

MATERIAL AND METHODS

Out of 15 F_1 hybrids, five F_1 s viz, M. Gota \times BB-54, Malapur \times BNDT, BR-14 \times BNDT, BR-14 \times PPC and BR-14 \times Kasral were selfed based on their performance and resistance towards the wilt during *rabi* 2014-15 to get F_2 population. Above Five F_2 population, with their F_1 s and their respective parents and resistant standard check (Swarna Pratibha) were used for the study of bacterial wilt inheritance. Each cross-involved bacterial wilt resistant genotypes (BB 54, BNDT, PPC and Kasral) as one of the parents, whereas, other parent involved in the cross represented commercial but susceptible cultivars (Manjari Gota, Malapur and BR-14). Forty days old seedlings were transplanted in the naturally sick plot available at research farm of Agricultural Botany, Dapoli during *rabi* 2015-16. Separate blocks were made for parents, F_1 and F_2 population. Each F_2 population consisted of 500 plants excepted BR-14 \times BNDT had 438 while parents, check and F_1 had a population of 15 plants each. Recommended package of practices were followed for raising the crop. The wilted plants were counted 90 days after transplanting (DAT) and final count was taken for calculating the inheritance pattern.

Observations were recorded on individual plant basis. A plant is considered as resistant to bacterial wilt if it doesn't wilt. The whole F_2 population was categorized into wilted and non-wilted population to know the genetics of resistance. The genetic ratios were tested based upon goodness of fit for inheritance using chi-square test.

RESULTS AND DISCUSSION

The experimental results obtained on the inheritance of bacterial wilt resistance in F_2 populations are given in Table 1. In the present study, the cross Mlp \times BNDT the segregation of F_2 s was in the ratio of 3(R):1(S) which suggested monogenic inheritance of resistance while in the crosses Mgt \times BB 54 and BR 14 \times PPC, a segregation of 9:7 of resistant and susceptibility were observed, indicating

that the resistance was governed by complementary gene interaction. Whereas, in the crosses BR 14 \times BNDT and BR 14 \times Kasral, the segregation in F_2 progenies did not fit to mono or di-genic ratios indicating that the resistance was controlled by polygene. Single dominant gene for resistance to bacterial wilt has also been reported in brinjal by Chaudhary and Sharma (1999), Ajjappalavara *et al.* (2008) and Bi-hao *et al.* (2009).

Ooze test was carried out to ensure the death of plants due to bacterial wilt. Fig. 1 and Fig. 2 show that microscopic slide of bacterial ooze out from roots of wilted plant at 30 and 60 DAT, respectively. Fig. 3 indicates that confirmation of bacterial wilt disease by regular testing of wilted plant through ooze test. All the plants showing wilting symptoms were subjected to ooze test up to final count 90 days after transplanting (DAT).

In literature, variable reports on the genetics/ inheritance of bacterial wilt resistance in various solanaceous vegetable crops have been reported. The parental lines used in this study were different from those of earlier workers and this variation along with differences in the strains of the pathogen and different environmental conditions of study may perhaps be the reason for the difference in results. Chaudhary (2000) has reported variable segregation patterns ranging from monogenic dominant and recessive to inhibitory type in different cross-combinations of brinjal. Neto *et al.* (2002) reported that inheritance of resistance to bacterial wilt in tomato plants is quantitative with partial dominance of the alleles. Linlin *et al.* (2003) concluded that the inheritance of bacterial wilt resistance as additive-dominant model in brinjal while bacterial wilt resistance was controlled by number of minor, major and cytoplasmic genes. Sharma and Sharma (2015) observed that there is a significant role of additive and dominance components and their interactions in the expression of bacterial wilt resistance in tomato. Bainsla *et al.* (2016) revealed that there was preponderance of recessive gene family wherein more than one gene acts in additive mode in brinjal.

Table 1. Mode of inheritance of bacterial wilt resistance in F₂ population of brinjal

S. No.	Crosses	F ₁	F ₂		Expected Ratio (R:S)	X ² value (Calculated)	X ² value (Table)	Type of gene action
			Observed frequency					
			Resistant	Susceptible				
1	Mgt x BB54	Resistant	270	230	3 : 1	117.6*	3.84	Complementary (9:7)
2	Mlp x BNDT	Resistant	393	107	3 : 1	3.46 ^{NS}	3.84	Monogenic dominant(3:1)
3	BR14 x BNDT	Moderately Susceptible	182	256	3 : 1	261.34*	3.84	?
4	BR14 x PPC	Moderately Susceptible	279	221	3 : 1	98.30*	3.84	Complementary (9:7)
5	BR14 x Kasral	Moderately Susceptible	184	316	3 : 1	389.13*	3.84	?

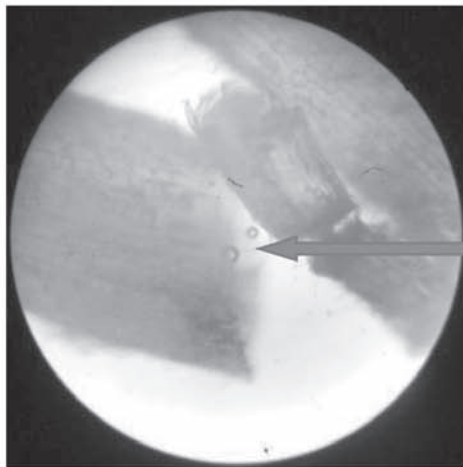


Fig. 1. Microscopic slide of bacterial ooze out at 30 DAT

Ooze out from cut roots of brinjal

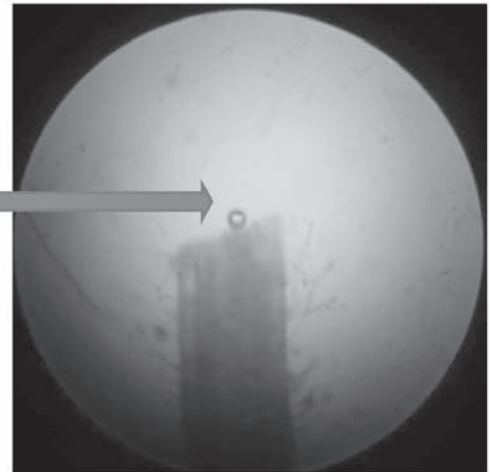


Fig. 2. Microscopic slide of bacterial ooze out at 60 DAT

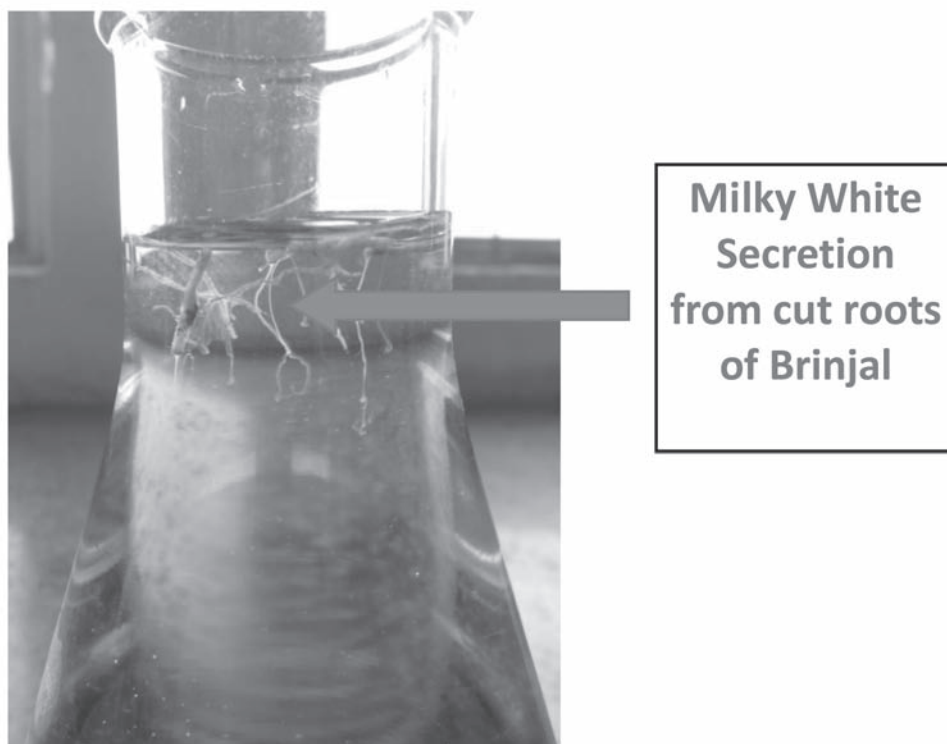


Fig 3. Regular testing of wilted plants by ooze test

CONCLUSION

It could be concluded that the inheritance of bacterial wilt resistance in brinjal plants under condition of naturally bacterial wilt infested soil was quantitative (polygenic) in nature. It shall, therefore, be more appropriate to carry out the genetics/ inheritance of resistance studies under controlled conditions and inoculating the plants with known strain(s) of the pathogen so as to have accurate information.

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INHERITANCE PATTERN OF THE DWARF GENE CONTROLLING PLANT HEIGHT IN RICE

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ABSTRACT

Dwarfism is a valuable trait in crop breeding, because it increases lodging resistance and decreases damages due to wind and rain. The experiment (*rabi* 2013 to *kharif* 2014) aimed to study the inheritance pattern of a dwarf mutant LND384, employing different F_2 progenies, developed by crossing with semi-dwarf, intermediate and tall groups. All the F_1 progeny showed heterosis over their parents towards tallness, indicating dominance of the trait. However, the plant height of F_2 progenies mostly skewed towards tall parent type or either short type, with platykurtic nature. Although bimodal distribution was seen with depression in the F_2 frequency curves of three crosses, namely LND384 x MTU1010, LND384 x Swarna and LND384 x Dular, also couldn't fit the expected mendalian ratio of 3:1. Hence, possibly the plant height in the dwarf derived population is controlled by major genes in combination with minor and/or modifier genes.

INTRODUCTION

Rice is the staple food for more than half of the world's population. Tropical Asia, accounting for over 90% of production and consumption of rice, had been cultivating low yielding, tall statured lodging-prone varieties until the advent of the non-lodging high yielding semi-dwarf varieties (short) in the mid-sixties. The short statured varieties, developed using Dee-Gee-Woo-Gen (DGWG), a spontaneous dwarf mutant as the donor, have enabled many countries in the region to achieve self-sufficiency in rice production in a short span of 15 years (Sasaki *et al.*, 2002 and Spielmeier *et al.*, 2002). The semi-dwarfism in DGWG is reported to be controlled by a single recessive gene, *sd1* (Cho *et al.*, 1994).

The success of DGWG- based varieties such as IR8 and Taichung Native 1 has made breeders all over to depend excessively on these two rice cultivars as source breeds for short stature trait. Hence, over 90% of the currently cultivated high yielding varieties have *sd1* gene as dwarfing source, from DGWG source (Cho *et al.*, 1994 and Spielmeier

et al., 2002). This forms the base for genetic homogeneity to high extent; render a vital character like plant height genetically vulnerable to sudden outbreak of diseases and insect pests. To overcome such an eventuality many efforts have been made since last three decades for broadening the genetic base through identification and use of alternate dwarfing gene sources (Singh *et al.*, 1979).

Genetic analysis of a large number of dwarfs of spontaneous and induced mutant origin has revealed that dwarfs, non-allelic to *sd1* are rare. However, a dwarf source LND384 (54cm \pm 1.86cm), which is non-allelic to *sd1* was identified in an in-house study using *sd1* gene specific markers. In order to precise use of the source material in the breeding programme and to broaden the genetic base for plant height, prior knowledge on gene action and its inheritance pattern is necessary. To understand the genetic nature of plant height, the current study is initiated with seven crosses involving the LND 384 as dwarf parent with genotypes of diverse plant height groups.

MATERIAL AND METHODS

Seven varieties/accessions that representing semi-dwarf (<110cm), intermediate (110-130cm) and tall (>130cm) (SES, IRRI, 2002) types were used in the study and are crossed in the following combinations viz. LND384 x MTU1010 (dwarf x semi-dwarf); LND84 x Swarna (dwarf x semi-dwarf); LND384 x BPT5204 (dwarf x tall); LND384 x Dular (dwarf x tall); LND384 x Pusa1121 (dwarf x tall); LND384 x PLA1100 (dwarf x tall) and LND384 x INRC10192 (dwarf x tall) during *kharif* 2013. The F_1 s were selfed to generate F_2 population during *rabi* 2013.

For each cross F_1 (20-25 plants), F_2 (100-200 plants) and parents (100-120 plants) were grown in adjacent plots during *kharif* 2014 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru. Plant spacing was given as 30cm x 20cm. Standard field management practices were followed throughout the crop growth period. The plant height was measured from the base of the plant to the tip of the tallest panicle. The phenotypic data was analyzed with data analysis package of MS-Excel Software, 2007 version.

Confirmation of F_1 Plants

Using polymorphic SSR (Simple Sequence Repeat) markers, the heterozygosity of F_1 plants for each cross were confirmed. The leaves from each parent were collected and frozen for DNA extraction. The cetyl trimethyl ammonium bromide (CTAB) method was used to extract genomic DNA from about 1.0g of young leaf tissue of each parent (Murray and Thompson 1980). The quality of DNA was checked using 0.8% agarose gel electrophoresis, and the DNA concentration was measured using Nanodrop reader.

The PCR reactions were carried out in 10 μ l volume, which contains 50ng rice genomic DNA, 5 pico moles each of forward and reverse primers, 0.1M deoxy nucleotide tri-phosphates (dNTPs), 1X Taq

buffer and 1U of Taq polymerase. The PCR conditions involve initial denaturation at 94°C for 3 min and 35 cycles of denaturation at 94°C for 45 sec followed by annealing at 54-58°C for 1 min and extension at 72°C for 45 sec and a final extension at 72°C for 10 min. The amplified PCR products were resolved on 3% agarose gel prepared in 1X TAE buffer stained with 10 μ M ethidium bromide and the resolved PCR bands were detected using Bio Rad Molecular Imager (Gel Doc-XR System). The gels were analyzed for the status of the genotype using SSR markers and the F_1 plants were confirmed for their heterozygosity.

RESULTS AND DISCUSSION

The study focused on characterizing and determining the inheritance pattern of plant height trait among the seven F_2 populations developed from crosses involving a dwarf rice mutant LND384 with 54cm \pm 1.86cm plant height (non-allelic to *sd1*) as female parent and semi-dwarf (<110cm), intermediate (110-130cm) and tall (>130cm) genotypes as male parents. The F_1 plants were confirmed for their heterozygosity by employing parental polymorphic SSR markers namely RM151 and RM562 (Fig. 1). The confirmed F_1 plants were selfed for generation of F_2 population.

Plant height of F_1 progeny

The F_1 generation of all seven crosses, irrespective of their pollen parental phenotypic group (semi-dwarf/intermediate/tall), showed heterosis towards tall plant nature except the progeny of LND384 x Swarna (Fig. 2), which is a semi-dwarf type. The inter-nodal lengths of major tiller of LND384 x Swarna F_1 plants showed clear demarcation of less elongation when compared to the other crosses (Fig. 2-II) and hence semi-dwarf type. Further, the internode number also five as against six in other crosses. Hence, it can be concluded that plant height is controlled by one or more major genes, apart from minor gene effects.

Plant height in F₂ progeny

The plant height among different F₂ populations ranges from 38cm (LND384 x Pusa1121) to 195cm (LND384 x Swarna and LND384 x Dular). This indicates that the tall plant height is not particularly confined to the crosses made between dwarf with tall and vice versa. Similarly, the minimum average plant height of 99cm was shown by LND384x BPT5204 cross progeny, whereas LND384 x Swarna (semi-dwarf type) progeny showed maximum average of 145.1cm.

Phenotyping for plant height trait of F₂ progeny exhibited transgressive segregation for all crosses beyond the range of both parents with 4.0% (LND384 x PLA1100) to 93.0% (LND384 x Dular), indicates that the gene combinations, of particularly dwarf with semi-dwarf and intermediate types played significant role towards generation of transgressive segregants.

The distribution pattern for plant height revealed that all the progenies showed non-normal and continuous segregation (Fig. 3). F₂ population for plant height was skewed towards tall parent type for all crosses, except of LND384 x BPT5204 (skewness = 1.40), with a range of -1.23 (LND384 x Pusa1121) to -1.82 (LND384 x MTU1010). The kurtosis study of plant height showed platykurtic value range of 2.0 (LND384 x INRC10192 and LND384 x Pusa1121) to 3.7 (LND384 x MTU1010) and hence the observed peaked distribution either towards tallness or short phenotype.

Together with the skewness and kurtosis studies, the non-normal distribution of the F₂ frequency curves of different progenies, couldn't fit a perfect 3:1 ratio. Although a digenic (bimodal) distribution is seen with depression at 100 cm-120 cm, 120 cm -140 cm and 80 cm -100 cm in the populations of three crosses viz. LND384 x MTU1010, LND384 x Swarna and LND384 x Dular, respectively, wherein these also couldn't fit the expected ratio. This can be explained through the effect of involvement

of minor and/or modifier genes along with major genes in controlling the plant height trait in the crosses involving dwarf as one of the parent. Even there are instances, where a cross between two dwarf strains gave the normal plant in the F₁.

Earlier studies on plant height inheritance pattern in rice, employing the progeny developed between parents with distinct differences in height have been found to be monogenic (Chang, 1970); digenic (Srividhya *et al.*, 2010 and Vemireddy *et al.*, 2015); polygenic (Anonymous, 1967) or governed by a major gene with interfering minor genes (Chang and Tagumpay, 1970). Thus, the inheritance pattern of plant height is still ambiguous and hence further studies at molecular level, would address the inheritance pattern. The molecular characterization of dwarf gene has initiated by our group, employing linkage mapping and candidate gene based approaches.

Dwarfism is a valuable trait in cereal breeding programmes, as it increases the lodging resistance by shortening the inter-nodal length and there by harvest index. For instance, the *sd1* gene has been reported to reduce plant height by 25% through proportional reduction in top five internode lengths; without any penalty on panicle length (Rutger, 1983). Initial attempts to study the genetics of semi-dwarfism using crosses of traditional tall varieties and semi-dwarf varieties suggested that semi-dwarfism is controlled by a single recessive gene, *sd1* (Cho *et al.*, 1994).

Dwarfing genes utilization in barley breeding programs has greatly increased barley yields, particularly in Asia and Europe (Ren *et al.* 2010 and Yu *et al.*, 2010) However, the dwarfing genes with potential applications in rice breeding are found to be very rare due to their pleiotropic effect on other yield and its component traits. In rice, more than 192 dwarfing genes were identified (Source: <http://shigen.nig.ac.jp/rice/oryzabase>). Genetical investigations on dwarfs has also been made by

several workers, and are reported as dominant, semi-dominant and recessive in inheritance pattern *viz.*, D53, Ssi1, Sdd(t), Dx, TID1, LB4D, Slr-f, D-h etc

(Mori *et al.*, 1973). Hence, identification of new dwarfing genes, studies on their inheritance pattern and their potential practical applications in future rice breeding is considered to be important.

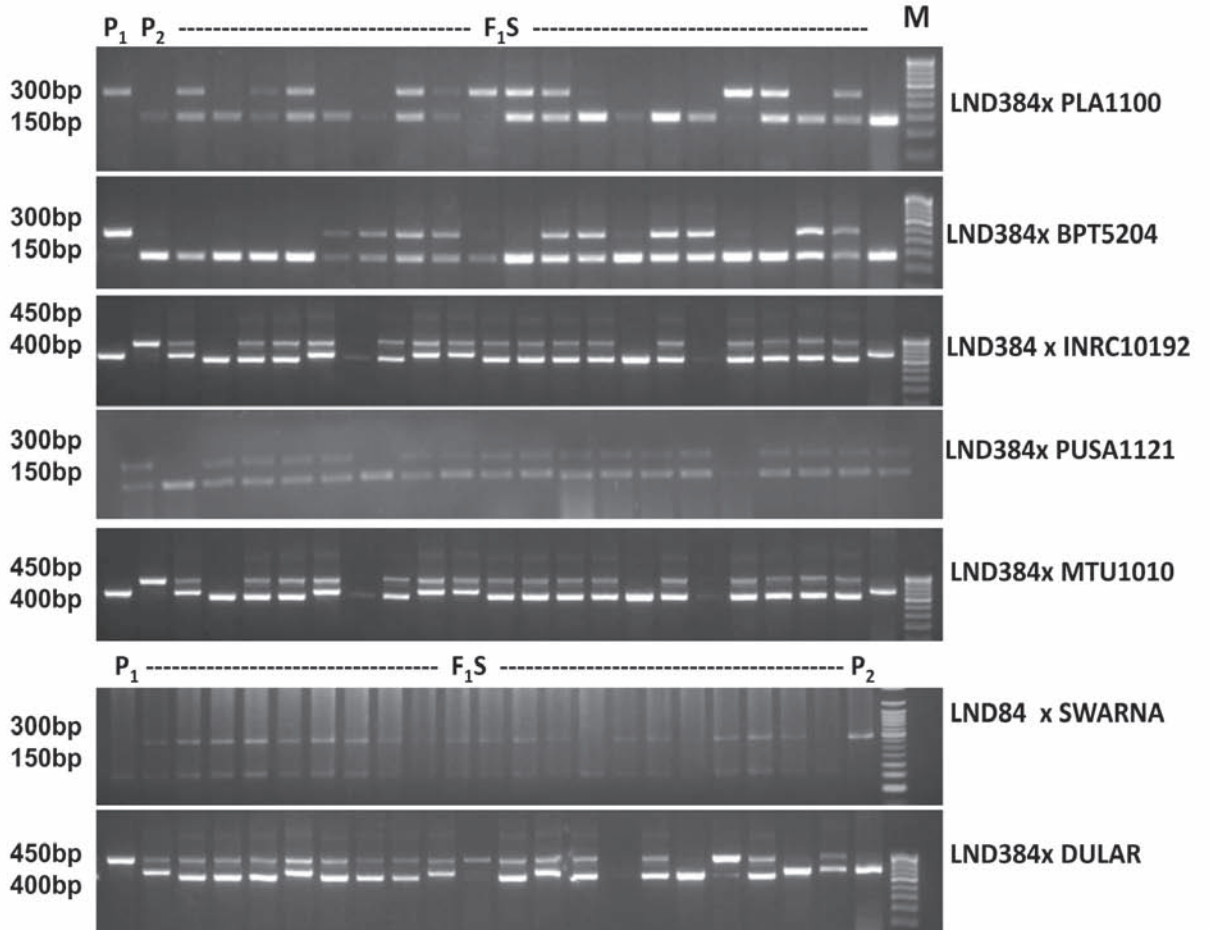


Fig.1. Confirmation of F₁s at molecular level using polymorphic SSR markers RM151 (400-450bp) and RM562 (150-300bp). The F₁ plants that having both parental alleles only selected for selfing to generate F₂ progenies. M: 50bp marker

INHERITANCE PATTERN OF PLANT HEIGHT IN RICE

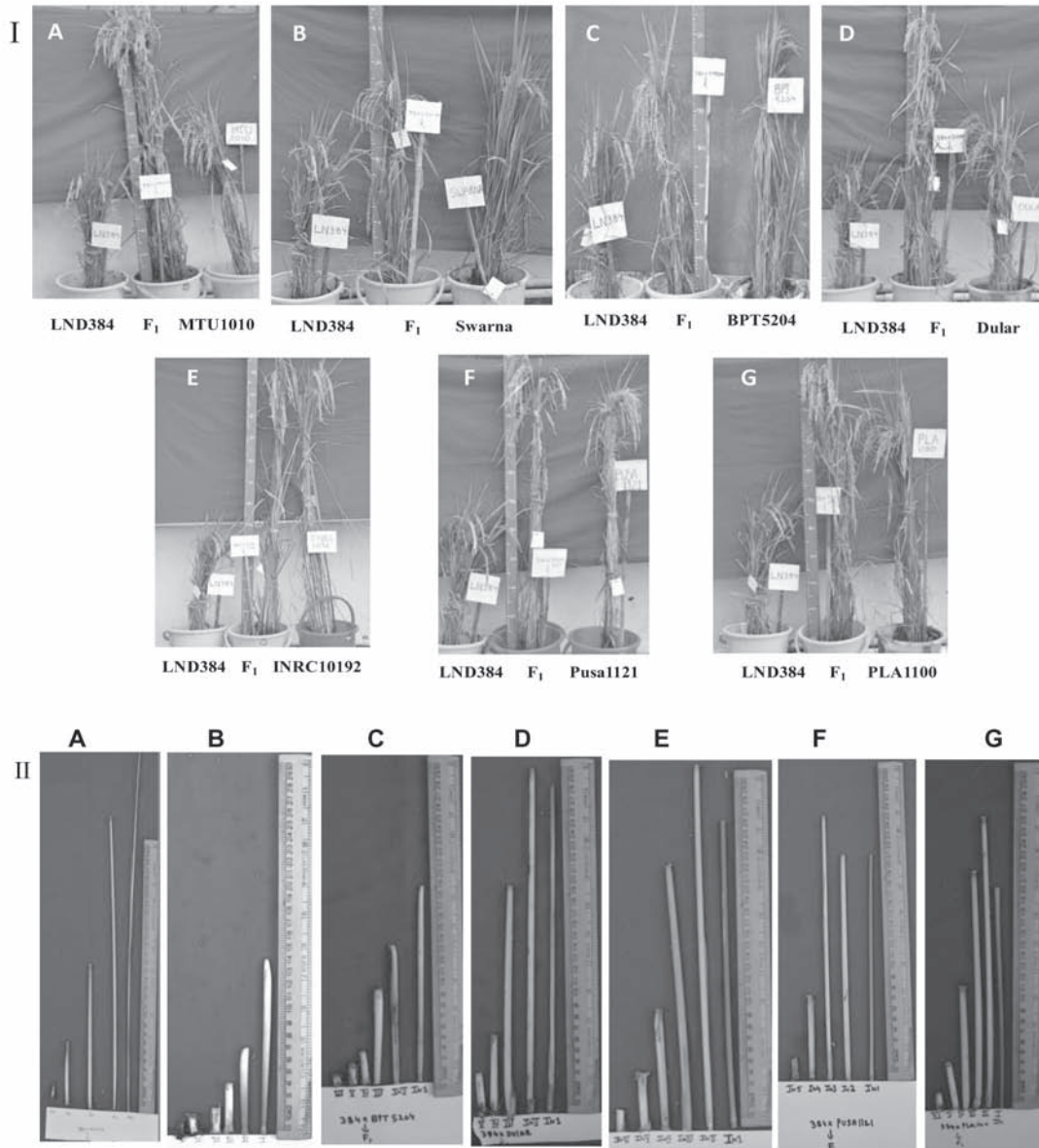


Fig . 2. Plant height phenotype (I); internode number and length variations (II) of F₁ plants of crosses involving LND384 with MTU1010 (A), Swarna (B), BPT5204 (C), Dular (D), INRC10192 (E), Pusa1121 (F) and PLA1100 (G)

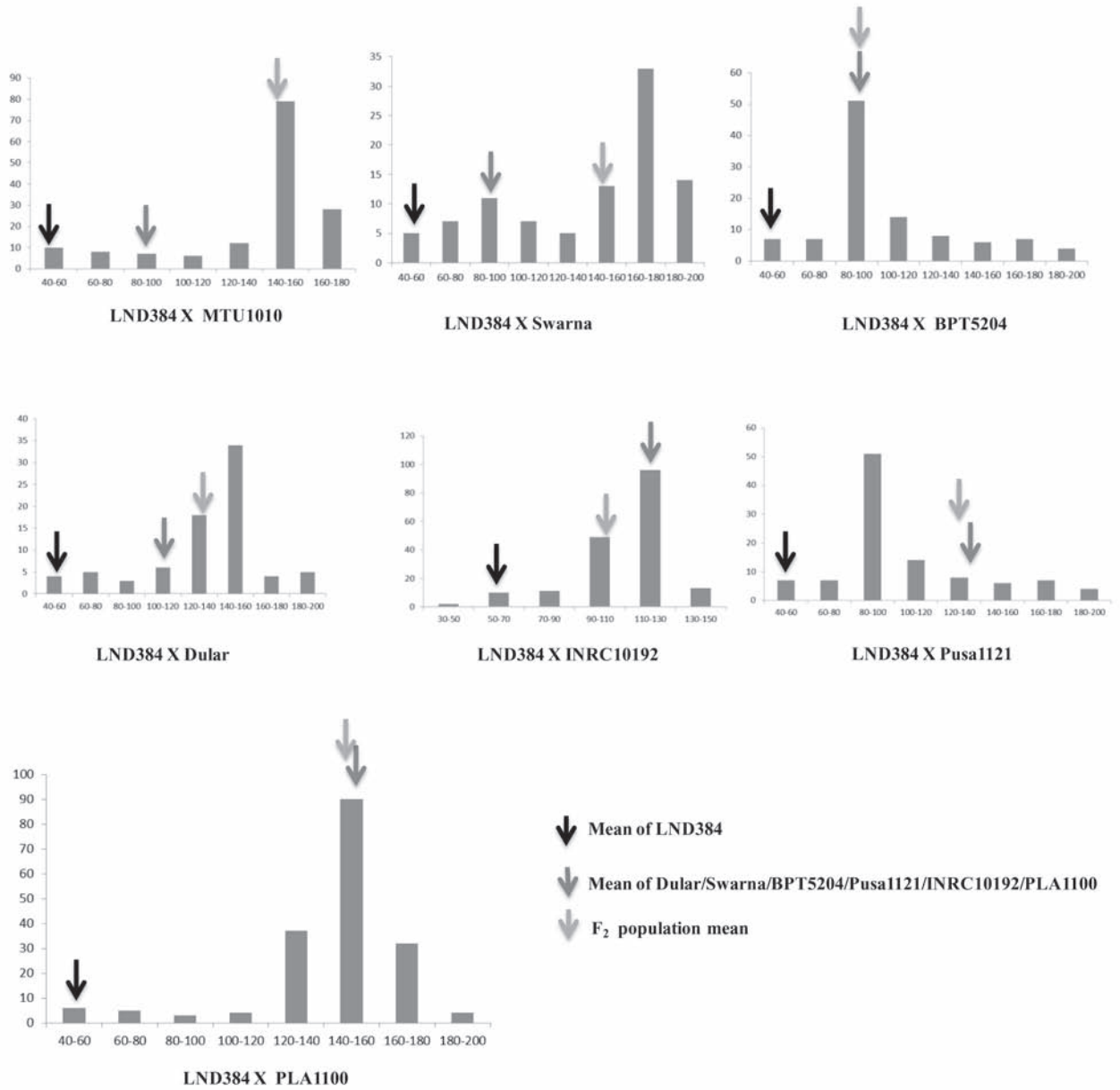


Fig 3. Distribution pattern of plant height trait for F₂ populations generated through independent crosses under study

Table1. Plant height in the F₂ populations derived from the crosses between dwarf (LND384) and semidwarf/intermediate/tall types

Plant Height (cm)										
Cross	Parents		F ₂ population							
	LND384 (N=10)	Pollen Parent (N=10)	Min	Max	Avg	SD	Kurt	Skew	TS (%)	Ratio (3:1)
LND384 x MTU1010	54 ±1.86	87	55	179	142.9	25.5	3.7	-1.82	91.3	NS
LND384 x Swarna		94	50	195	145.1	28.5	3.2	-1.75	89.2	NS
LND384 x BPT5204		98	48	179	99.0	22.2	3.2	1.40	21.0	NS
LND384 x Dular		105	52	195	138.9	26.7	2.3	-1.29	93.3	NS
LND384 x INRC10192		125	41	147	109.5	19.0	2.0	-1.34	17.1	NS
LND384 x Pusa1121		132	38	175	124.9	29.0	2.0	-1.23	12.0	NS
LND384 x PLA1100		149	43	185	142.5	27.2	3.6	-1.80	4.0	NS

Min: minimum; Max: maximum; Avg: average; SD: standard deviation; Kurt: kurtosis; Skew: skewness; TS: transgressive segregants

CONCLUSION

From the current study, it can be concluded that, tall character in F₁ involving a dwarfing source as parent, was dominant in nature. However, F₂ distribution of the seven crosses although resembles continuous variation typical to a quantitative trait, doesn't follow an expected mendalian ratio. The skewness and kurtosis studies imply the involvement of many minor and/or modifier genes along with major genes in the control of F₂ plant height, as there is a large range of variation for plant height found in all three phenotypic parental crosses. Hence, culmination of phenotypic studies with molecular level approaches would result in better understanding of the inheritance nature of rice dwarfing gene(s) that could be used in future breeding programmes.

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EFFECT OF PLANT GEOMETRY AND FERTILIZER LEVELS ON YIELD, YIELD ATTRIBUTES AND QUALITY CHARACTER OF COWPEA (*Vigna unguiculata* L. Walp)

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ABSTRACT

Field experiment was conducted during *kharif* season of 2013 to study the influence of plant geometry and fertilizer levels on growth and yield of cowpea (*Vigna unguiculata* L. Walp) under rainfed condition with a view to study the response of cowpea to different spacing and levels of fertilizers. Cowpea crop grown in *kharif* season produced significantly higher yield attributes, seed yield and protein content with wider spacing of 45 cm x 10 cm and fertilizer level *i.e.* application of 30:60:00 kg NPK ha⁻¹.

INTRODUCTION

The cowpea (*Vigna unguiculata* L. Walp.) belongs to family Leguminaceae with subfamily Papilionaceae. Its origin and subsequent domestication is associated with pearl millet and sorghum in Africa. It is a broadly adapted and variable crop cultivated around the world primarily for seed, also as a vegetable, green pods, fresh shelled green peas and dried peas, a cover crop and for fodder. Cowpea an important multipurpose grain legume. The mature cowpea seed contains 24.8% protein, 63.6% carbohydrate, 1.9% fat, 6.3% fibre, 0.00074% thiamine, 0.00042% Riboflavin and 0.00281% Niacin (Shaw, 2007). The protein concentration ranges from about 3% to 4% in green leaves, 4% to 5% in immature pods and 25% to 30% in mature seeds. It is also rich in source of Ca and Fe. It is grown as green manure crop for soil improvement. Among the grain legumes the green pods of cowpea are used as vegetable. It has ability to fix atmospheric nitrogen in soil in association with symbiotic bacteria under favourable condition.

The largest producer is Africa, Brazil, Haiti, India, Myanmar, Srilanka, Australia, Bosnia and Herzegovina also have significant production. Worldwide cowpeas are cultivated in approximately 8 mha. The total world production is estimated about

3.3 million tons of dry grain. Area under cowpea in India is 3.9 million hectares with a production of 2.21 million tonnes with the national productivity of 683 kg ha⁻¹ (Singh *et al.*, 2012). Area under cowpea in Maharashtra was 11,800 ha with an average productivity of 400 kg ha⁻¹ (FAO, 2012).

There are many reasons for low productivity of cowpea in Maharashtra, *viz.*, sowing time, plant population, weed management, insect pest attack, nutrient supply, etc. The primary component of cowpea yield is number of pods plant⁻¹ and weight of individual pod. Number of pods plant⁻¹ is directly affected by planting density which changes rapidly with the close spacing or with increased seed rate. Thus, yield level can be increased substantially by manipulating certain cultural practices like spacing, seed rate and nutrient supply. Thus, adoption of suitable crop geometry will go a long way increasing yield of cowpea. Naim and Jaberlaldar (2010) reported that plant density had a significant effect on most of the growth attributes measured. Increasing plant population increased plant height and decreased number of leaves per plant and leaf area index (LAI). Cowpea is a leguminous crop and can fix atmospheric 'N' with the help of rhizobium bacteria. Deficiency of N, P and K are among major constraints on higher crop productivity in tropical regions. Hence,

for optimum yield crop need to be fertilized properly. The recommended dose of fertilizer for cowpea is 25:50 kg NP ha⁻¹, farmers are following the recommended dose of fertilizer and using low fertilizer level. Soil fertility status has deteriorated over the years which resulted in low productivity.

MATERIAL AND METHODS

The present field experiment was conducted during *kharif* season of 2013 at the Experimental Farm, Agronomy Department, College of Agriculture, Latur (Maharashtra). Geographically Latur is situated between 18°05' to 18°75' North latitude and between 76°25' to 77°25' East longitude, its height above mean sea level is about 633.85 m and has subtropical climate. To study the influence of plant geometry and fertilizer levels on growth and yield of cowpea (*Vigna unguiculata* L. Walp) under rainfed condition with a view to study the response of cowpea to different spacing and levels of fertilizers.

The experimental field was levelled and well drained. The soil of the experimental plot was clayey in texture, low in available nitrogen (225 kg ha⁻¹), very low in available phosphorus (15.82 kg ha⁻¹), very high in available potassium (526 kg ha⁻¹). The soil was moderately alkaline in reaction (pH). The environmental conditions prevailed during experimental period were favourable for normal growth and development of cowpea crop. The present experiment was laid out in Factorial Randomized Block Design with three replications. The treatments were consisting of two different factors; one was spacing and the other was fertilizer levels. **First Factor** - Spacing (Plant Population) S₁ - 30 cm × 10 cm, S₂ - 30 cm × 15 cm, S₃ - 45 cm × 10 cm and S₄ - 45 cm × 15 cm, **Second factor** - Fertilizer levels: F₁ - 80 % RDF (20:40:00 kg NPK ha⁻¹), F₂ - 100 % RDF (25:50:00 kg NPK ha⁻¹) and F₃ - 120 % RDF (30:60:00 kg NPK ha⁻¹).

The gross plot size of each experimental unit was 5.4 m × 4.5 m and net plot size S₁ - 4.8 m × 3.5 m, S₂ - 4.8 m × 3.6 m, S₃ - 4.5 m × 3.5 m and S₄ - 4.5 m × 3.6 m, respectively. Pure seed of cowpea Var. Konkan Sadabahar was brought from

B.S.K.K.V., Dapoli. Cowpea was sown on 4th July 2013. The sowing was done by dibbling with 2- 3 seeds per hill at a distance of 30 cm² × 10 cm², 30 cm² × 15 cm², 45 cm² × 10 cm², 45 cm² × 15 cm² at about 5 cm depth by keeping seed rate @ 15 kg ha⁻¹. The object of dibbling was to maintain fairly uniform plant population in each row and gap filling was done 10 days after sowing to maintain optimum plant stand.

RESULTS AND DISCUSSION

Effect of Spacing

Data from Table 1 showed that the wider spacing (45 cm × 15 cm) recorded significantly higher pod yield plant⁻¹ (8.16 g), higher mean seed yield (6.16 g plant⁻¹) and highest seed index (7.35 g) followed by the spacing 45 cm × 10 cm (6.94 g, 5.24 g and 7.27, respectively) which was higher than narrow spacing. It might be due to wider spacing which reduced crowding of cowpea and got more sunlight, more nutrients resulted in higher reproductive growth of cowpea. These results are in conformity with the results of Patel *et al.* (2008).

Data on mean seed yield (kg ha⁻¹), biological yield (kg ha⁻¹), harvest index (HI) as influenced by different levels of spacing was found significant with the wider spacing of 45 cm × 10 cm and recorded significantly higher seed yield (1143 kg ha⁻¹), biological yield (3780 kg ha⁻¹) and harvest index (30.23 %) was followed by the closer spacing 30 × 15 cm (998 kg ha⁻¹, 3410 kg ha⁻¹ and 29.21 %, respectively). This variation in seed yield, biological (kg ha⁻¹) might be due to different spacings which had different plant population ha⁻¹. Similar results were reported by Singh *et al.* (2012).

The straw yield (kg ha⁻¹) as influenced by different levels of spacing was found to be significant. The narrow spacing of 30 cm × 10 cm (3,33,333 plants ha⁻¹) recorded maximum straw yield (2733 kg ha⁻¹) which was found significantly superior to other spacings and was at par with spacing 45 cm × 10 cm (2,22,222 plants ha⁻¹) and recorded straw yield of 2637 kg ha⁻¹. This might be due to higher plant

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population in narrow spacing which resulted in more vegetative growth. These results are in conformity with the results of Santiesteban *et al.* (2002).

The effect of different levels of spacing on protein content was found to be non significant. The wider spacing (45 cm x 15 cm) recorded the maximum protein content (23.64%) and protein yield (212 kg ha⁻¹) which was higher than narrow spacings. A significantly increase in grain and straw yield with wider spacing might have improved the protein content and protein yield.

Effect of Fertilizer

The pod yield plant⁻¹ (6.57 g), yield plant⁻¹ (4.91 g) and seed index (7.30) were found significantly higher with the application of 30:60:00 kg NPK ha⁻¹ over rest of the fertilizer levels. The increased fertilizer levels stimulated photosynthesis rate which ultimately stimulated the pod and seed formation that resulted highest number of seeds pod⁻¹. Similar

results were also observed by Sudhavani (2005) and Singh *et al.* (2007). From the data (Table 2) on mean seed yield (kg ha⁻¹), straw yield (kg ha⁻¹) and biological yield (kg ha⁻¹) showed that the application of 30:60:00 kg NPK ha⁻¹ recorded significantly higher seed yield, straw yield and biological yields (1049, 2643 and 3692 kg ha⁻¹, respectively) over the rest of the fertilizer levels. The highest harvest index was observed (28.86%) due to the application of 30:60:00 kg NPK ha⁻¹. This can be due to higher growth and yield contributing characters with higher level of fertilizer resulted in higher seed, straw and biological yield.

The higher protein content (23.16%) and higher protein yield (243 kg ha⁻¹) was recorded by the application 30:60:00 kg NPK ha⁻¹ over other levels of fertilizer. Similar results was reported by Shekara *et al.* (2012). The result might be due to increased levels of fertilizer which helped in the synthesis of amino acids (cystine, cysteine and methionine) which are the sources of protein.

Table 1. Pod yield (g plant⁻¹), seed yield (g plant⁻¹), number of seeds plant⁻¹ and seed index (g) as influenced by different treatments

Treatment	Pod yield (g plant ⁻¹)	Seed yield (g plant ⁻¹)	No. of seeds plant ⁻¹	Seed index (g)
Spacing (S) (cm x cm)				
S ₁ - 30 x 10	3.97	3.02	41.59	7.26
S ₂ - 30 x 15	6.08	4.60	63.45	7.15
S ₃ - 45 x 10	6.94	5.24	72.25	7.27
S ₄ - 45 x 15	8.16	6.16	84.65	7.35
S.E.	0.10	0.08	1.10	0.16
C.D. at 5 %	0.31	0.23	3.25	NS
Fertilizer Levels (F) (kg NPK ha⁻¹)				
F ₁ - 20:40:00	6.10	4.61	63.56	7.25
F ₂ - 25:50:00	6.21	4.69	64.66	7.23
F ₃ - 30:60:00	6.57	4.91	68.26	7.30
S.E.	0.09	0.06	0.96	0.14
C.D. at 5 %	0.27	0.20	2.81	NS
Interaction (S x F)				
S.E.	0.18	0.13	1.92	0.28
C.D. at 5 %	NS	NS	NS	NS

NS - Non - Significant

Table 2. Seed yield (kg ha⁻¹), straw yield (kg ha⁻¹), biological yield (kg ha⁻¹) and harvest index (%) as influenced by different treatments

Treatment	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
Spacing (S) (cm x cm)				
S ₁ - 30 x 10	968	2733	3701	26.15
S ₂ - 30 x 15	998	2418	3416	29.21
S ₃ - 45 x 10	1143	2637	3780	30.23
S ₄ - 45 x 15	897	2367	3264	27.48
S.E.	17	70	69	-
C.D. at 5 %	52	207	203	-
Fertilizer levels (F)(kg NPK ha⁻¹)				
F ₁ - 20:40:00	967	2613	3351	27.01
F ₂ - 25:50:00	987	2589	3577	27.60
F ₃ - 30:60:00	1049	2643	3692	28.86
S.E.	15	61	60	-
C.D. at 5 %	45	179	176	-
Interaction (S x F)				
S.E.	31	122	120	-
C.D. at 5 %	NS	NS	NS	-

NS - Non - Significant

Table 3. Protein content (%) and protein yield (kg ha⁻¹) as influenced by different treatments

Treatment	Protein content (%)	Protein yield (kg ha ⁻¹)
Spacing (S) (cm x cm)		
S ₁ - 30 x 10	22.80	220
S ₂ - 30 x 15	23.12	230
S ₃ - 45 x 10 S ₄ - 45 x 15	23.2123.64	265212
S.E.	0.62	9.1
CD at 5 %	NS	26.3
Fertilizer levels (F) (kg NPK ha⁻¹)		
F ₁ - 20:40:00	22.82	220
F ₂ - 25:50:00	23.14	228
F ₃ - 30:60:00	23.16	243
S.E.	0.51	14.3
CD at 5 %	NS	41
Interaction (S x F)		
S.E.	0.98	15
CD at 5 %	NS	NS

NS - Non - Significant

CONCLUSION

Cowpea crop grown in *kharif* season produced significantly higher yield attributes, seed yield and protein content with wider spacing of 45 cm x 10 cm and fertilizer level *i.e.* application of 30:60:00 kg NPK ha⁻¹.

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BIOEFFICACY OF DIFFERENT BIORATIONAL INSECTICIDES FOR THE MANAGEMENT OF SPOTTED STEM BORER, *Chilo partellus* (SWINHOE) IN MAIZE (*Zea mays* L.)

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ABSTRACT

Field experiments were conducted at Agricultural Research Station, Darsi during *Rabi* 2014-15 and *Rabi* 2015-16 to evaluate the bio-efficacy of biorational insecticides against *Chilo partellus* on maize. Among the different biorationals tested, chlorantraniliprole 18.5% SC was found to be significantly superior over the other treatments with 79.60 per cent mean reduction of foliage damage over untreated control. This was followed by chlorantraniliprole 0.4% GR (72.80%) and spinosad 45% SC (72.63%) in the descending order of their efficacy which were at par. Chlorantraniliprole 18.5% SC, spinosad 45% SC and chlorantraniliprole 0.4% GR in that order proved significantly superior in reducing the larval population of *C. partellus* (0.18, 0.32 and 0.45 per plant), dead hearts (1.71, 2.45 and 2.99%), tunnel length (1.62, 2.52 and 3.32%) and exit holes caused by *C. partellus* (0.52 and 0.62 per plant), respectively. The cumulative effect of biorational treatments on yield indicated that chlorantraniliprole 18.5% SC recorded the highest yield (8268.85 kg ha⁻¹) with 108.1 per cent yield increase over untreated control. Spinosad 45% SC (7936.51 kg ha⁻¹) and chlorantraniliprole 0.4% GR (7488.10 kg ha⁻¹) were the next better treatments with 99.8 and 88.4 per cent yield increase over untreated control. Maximum IBCR was recorded in monocrotophos 36% SL (18.52) followed by chlorantraniliprole 18.5% SC (11.28).

INTRODUCTION

Maize (*Zea mays* L.) is the principal cereal crop that occupied 1063 thousand hectares of area under cultivation with an annual production of 4968 thousand tones and 4673 kg ha⁻¹ productivity in Andhra Pradesh (Yadav, 2015). It has great importance as human food as well as providing the most important ingredient of cattle fodder and poultry feed. Among the 250 species of insects and mite species attacking maize in field and storage conditions, spotted stem borer, *Chilo partellus* Swinhoe is the most serious one causing 26.7 to 80.4 per cent yield losses in different agro-climatic regions of India (Anuradha, 2013).

The use of insecticides for stem borer control is often uneconomical and beyond the reach of poor farmers (Deepthi *et al.*, 2008). Further, the concern over indiscriminate use of chemical pesticides and the adverse effect of pesticides on the environment warrant eco-friendly approaches in pest management programs (Ramesh *et al.*, 2012). Biorational

strategies employing insect growth regulators, natural products, botanical preparations and entomopathogenic microbials are gaining significance as possible alternative measures for the sustainable management of spotted stem borer in maize. However, several workers have explored the utility of biorational insecticides for the management of maize stem borer under field conditions with Neem Seed Kernel Extract (NSKE), *Bacillus thuringiensis* (Berliner) (Deepthi *et al.*, 2008), but very little information is available on the activity of microbial pathogens especially fungus like *Beauveria bassiana* (Balsamo) Vuillemin and *Metarhizium anisopliae* (Metschinkoff) Sorokin under field conditions. In this context, the present study was undertaken to evaluate the bio-efficacy of botanical pesticides, entomogenous microbes, insect growth regulators and natural insecticides in the management of maize stem borer *C. partellus*.

Table 1. Foliage damage of maize by *C. partellus* as influenced by the application of biorational insecticides during Rabi 2014-15 and 2015-16 (Pooled data)

T. No.	Insecticide	Dose ha ⁻¹	% Foliage damage reduction over control										
			First application			Second application				Pooled mean			
			PTC	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT	21 DAT				
T ₁	Azadirachtin (10,000 ppm)	1000 ml	21.70	34.50 (35.73) ^b	36.40 (37.07) ^{ef}	40.42 (39.20) ^{de}	38.71 (38.47) ^{bc}	39.88 (39.17) ^{cde}	41.04 (39.86) ^c	38.49 (38.36) ^{de}			
T ₂	<i>Beauveria bassiana</i>	10 ⁸ spores	20.87	37.64 (37.79) ^b	27.24 (31.33) ^f	27.75 (31.60) ^e	20.52 (26.86) ^{cd}	30.47 (33.39) ^{de}	30.44 (33.25) ^{cd}	29.01 (32.53) ^e			
T ₃	<i>Metarhizium anisopliae</i>	10 ⁸ spores	17.85	34.35 (34.64) ^b	28.71 (32.23) ^f	47.16 (43.37) ^{cd}	18.20 (24.30) ^d	22.18 (27.26) ^e	15.97 (22.82) ^d	27.76 (31.79) ^e			
T ₄	<i>Bacillus thuringiensis</i> (Halt 5%WP)	1 kg	18.44	68.18 (56.12) ^a	55.97 (48.45) ^{cd}	59.30 (50.54) ^{abc}	52.13 (46.32) ^b	58.05 (49.83) ^{bc}	51.32 (45.99) ^{bc}	57.49 (49.37) ^c			
T ₅	Novaluron 10% EC	500 ml	18.98	44.93 (42.06) ^b	45.65 (42.51) ^{de}	49.15 (44.53) ^{cd}	44.65 (41.94) ^b	42.18 (40.32) ^{cd}	46.06 (42.74) ^c	45.44 (42.37) ^d			
T ₆	Spinosad 45% SC	150 ml	15.90	70.18 (56.96) ^a	73.75 (59.48) ^{ab}	62.48 (52.37) ^{abc}	81.11 (64.48) ^a	77.09 (61.99) ^{ab}	71.17 (57.78) ^{ab}	2.63 (58.57) ^{ab}			
T ₇	Chlorantraniliprole 18.5% SC	150 ml	15.91	78.31 (62.30) ^a	80.28 (63.69) ^a	72.77 (58.62) ^a	83.07 (65.80) ^a	82.13 (65.50) ^a	1.03 (64.72) ^a	9.60 (63.22) ^a			
T ₈	Chlorantraniliprole 0.4% GR	10 kg	20.00	71.49 (57.93) ^a	73.39 (59.07) ^{ab}	70.00 (56.86) ^{ab}	75.87 (61.72) ^a	74.16 (59.81) ^{ab}	71.92 (58.19) ^{ab}	2.80 (58.75) ^{ab}			
T ₉	Carbofuran 3G	10 kg	19.21	68.24 (55.80) ^a	65.39 (54.00) ^{bc}	61.81 (51.88) ^{abc}	75.32 (60.31) ^a	70.85 (57.51) ^{ab}	68.55 (55.96) ^{ab}	8.36 (55.80) ^{bc}			
T ₁₀	Monocrotophos 36% SL	800 ml	20.70	73.28 (58.91) ^a	74.16 (59.53) ^{ab}	55.03 (47.98) ^{bcd}	75.23 (60.52) ^a	68.25 (55.75) ^{ab}	70.86 (57.40) ^{ab}	69.47 (56.49) ^b			
T ₁₁	Untreated control	—	20.50	—	—	—	—	—	—	—			
		SEM±	1.49	4.21	2.05	3.13	4.59	4.30	4.33	2.25			
		CD @ 5%	NS	12.43	6.04	9.24	13.54	12.68	12.79	6.64			
		CV (%)	9.96	16.10	8.01	12.51	17.81	16.70	17.26	8.79			

Values in parentheses are arc sine transformed values DAT – Days after treatment, NS: Non Significant, PTC – Pre Treatment Count
 Bt – *Bacillus thuringiensis* Serovar Kurstaki H 3a, 3b, 3c; 5% WP, Halt, 5X10⁷ spore/mg, make - Biostadt
 In a column means followed by same alphabet do not differ significantly by CD (P=0.05)

MATERIAL AND METHODS

Field experiments were laid out in a Randomized Block Design (RBD) at Agricultural Research Station, Darsi with eleven treatments and replicated thrice including untreated control to evaluate the bio-efficacy of biorational pesticides against *C. partellus* on maize. The size of each plot was 16.8 m² with seven rows and 20 plants per row. The popular maize hybrid 30V92 was selected for the experiment and was sown during *Rabi* season of 2014-15 and 2015-16 with 0.6 m x 0.2 m spacing between row to row and plant to plant. For uniform infestation in trial plots, egg masses of *C. partellus* at black-head stage obtained from laboratory cultures were taken to experimental site and 10 egg masses were pinned randomly on whorl leaves of 15-20 day old plants in the central four rows in each treatment plot. A total of 330 egg masses were placed in the entire experimental plot.

The biopesticides viz., *Beauveria bassiana* Vuillemin and *Metarhizium anisopliae* Metchnikoff were obtained from Department of Microbiology, Post Harvest Technology Centre, Bapatla. *Bacillus thuringiensis* Serovar Kurstaki H 3a, 3b, 3c; (Halt 5% WP, 5X10⁷ spore/mg) manufactured by Biostadt was obtained locally. The standard checks used were monocrotophos 36 SL and carbofuran 3G. All the treatments were imposed two times, i.e., 25th and 47th day after emergence of the crop.

Observations on stem borer damage was recorded as fresh leaf damage with shot holes in randomly selected 10 plants in each replication of the treatment leaving border rows to avoid border effect. The observations were recorded one day before treatment as pre-treatment count and at 7, 14 and 21 days after each spray as post-treatment counts and per cent infestation / damage was worked out. Observations recorded on 21st day after first spray served as the pre-treatment count for the second spray. For the extent of infestation, dead hearts were also used as criteria for infested plants. The

individual data of dead hearts at 30 (after first spray) and 50 (after second spray) days after treatment was taken which was then converted into total per cent dead heart damage on the basis of total plant stand and mean per cent damage for the season. At the time of harvest, the total number of larvae per 10 plants was recorded by destructive sampling. The selected plants were uprooted and number of exit holes was recorded. Next, the stems were split opened to count the number of larvae or pupae of *C. partellus* and the tunnelling length was recorded. Per cent stem tunnelling was calculated on the basis of total tunneled length divided by plant height of affected plant. Average per cent stem tunneling per plot was calculated by dividing average tunnel length by average length of plants taken for tunnelling observation. At 7, 14 and 21 DAE, observation for natural enemies was also made in the treatment plots of each replication.

The net plots were harvested, dried, shelled and cleaned replication wise separately excluding border rows and yield per plot was expressed as kg per plot, based on which yield per hectare was calculated. The cost economics of each treatment was calculated to find out the most economic method of stem borer management in maize. Benefit-cost ratio was calculated by dividing the extra benefit attained from enhanced yield by the extra cost incurred for each treatment. The percentage values and mean population data were duly transformed into the corresponding angular and square root transformed values and were subjected to statistical analysis using the analysis of variance for randomized block design. Critical difference values were calculated at 5% probability level and the treatment mean values were compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The overall cumulative efficacy of all the observations made at 7, 14 and 21 days after each spray of different biorational insecticides during two

Table 2. Effect of biorational insecticides use on the damage caused by *C. partellus* in maize during Rabi 2014-15 and 2015-16

T. No.	Insecticide	Dose ha ⁻¹	Per cent dead hearts											
			Rabi 2014-15				Rabi 2015-16				Pooled			
			30 DAE	50 DAE	Mean	30 DAE	50 DAE	Mean	30 DAE	50 DAE	Mean	30 DAE	50 DAE	Mean
T ₁	Azadirachtin (10,000 ppm)	1000 ml	8.85 (17.28) ^b	9.33 (17.77) ^{bcd}	9.09 (17.53) ^{bc}	6.87 (15.15) ^b	11.50 (19.83) ^b	9.19 (17.64) ^b	7.86 (16.25) ^b	10.42 (18.83) ^{bc}	9.14 (17.59) ^{bc}			
T ₂	<i>Beauveria bassiana</i>	10 ⁸ spores	5.08 (12.95) ^{cd}	9.97 (18.27) ^{bc}	7.52 (15.91) ^{bcd}	4.70 (12.39) ^{cd}	10.89 (19.20) ^b	7.80 (16.13) ^b	4.89 (12.67) ^{cd}	10.43 (18.85) ^{bc}	7.66 (16.06) ^c			
T ₃	<i>Metarhizium anisopliae</i>	10 ⁸ spores	7.78 (16.21) ^{bc}	12.68 (20.68) ^{ab}	10.23 (18.61) ^b	6.56 (14.84) ^{bc}	12.09 (20.35) ^b	9.32 (17.78) ^b	7.17 (15.54) ^{bc}	12.39 (20.55) ^b	9.78 (18.21) ^b			
T ₄	<i>Bacillus thuringiensis</i> (Halt 5%WP)	1 kg	2.64 (9.20) ^e	9.09 (17.55) ^{bcd}	5.86 (14.01) ^{de}	2.21 (8.41) ^{ef}	7.61 (16.02) ^c	4.91 (12.80) ^{cd}	2.42 (8.81) ^{ef}	8.35 (16.80) ^c	5.39 (13.42) ^{de}			
T ₅	Novaluron 10% EC	500 ml	3.85 (11.12) ^{de}	9.39 (17.79) ^{bcd}	6.62 (14.83) ^{cde}	2.66 (9.34) ^{ef}	7.38 (15.74) ^c	5.02 (12.94) ^c	3.26 (10.28) ^{def}	8.38 (16.82) ^c	5.82 (13.93) ^d			
T ₆	Spinosad 45% SC	150 ml	1.92 (7.86) ^{ef}	3.62 (10.88) ^{ef}	2.77 (9.49) ^{gh}	1.62 (7.22) ^g	2.65 (9.36) ^f	2.14 (8.37) ^g	1.77 (7.54) ^g	3.13 (10.15) ^g	2.45 (8.95) ^{gh}			
T ₇	Chlorantraniliprole 18.5% SC	150 ml	0.96 (4.60) ^f	2.40 (8.54) ^f	1.68 (7.02) ^h	0.87 (5.28) ^g	2.61 (9.26) ^f	1.74 (7.58) ^g	0.91 (5.27) ^g	2.51 (9.06) ^g	1.71 (7.45) ^h			
T ₈	Chlorantraniliprole 0.4% GR	10 kg	1.92 (7.87) ^{ef}	4.07 (11.39) ^{ef}	3.00 (9.87) ^{gh}	2.28 (8.53) ^{ef}	3.70 (11.10) ^{ef}	2.99 (9.94) ^{ef}	2.10 (8.23) ^{ef}	3.89 (11.30) ^{ef}	2.99 (9.91) ^g			
T ₉	Carbofuran 3G	10 kg	3.59 (10.89) ^{de}	6.51 (14.72) ^{cde}	5.05 (12.95) ^{def}	3.25 (10.37) ^{de}	4.06 (11.62) ^{de}	3.65 (11.02) ^{de}	3.42 (10.64) ^{de}	5.28 (13.27) ^{de}	4.35 (12.02) ^{de}			
T ₁₀	Monocrotophos 36% SL	800 ml	2.93 (9.67) ^{de}	5.90 (13.93) ^{de}	4.41 (11.98) ^{efg}	2.70 (9.23) ^{ef}	5.17 (13.13) ^d	3.94 (11.38) ^{cde}	2.81 (9.46) ^{ef}	5.54 (13.54) ^d	4.18 (11.69) ^{ef}			
T ₁₁	Untreated control	—	13.19 (21.30) ^a	16.32 (23.82) ^a	14.76 (22.60) ^a	12.31 (20.54) ^a	15.96 (23.55) ^a	14.14 (22.09) ^a	12.75 (20.93) ^a	16.14 (23.70) ^a	4.45 (122.35) ^a			
		SEM±	1.24	1.42	1.08	0.93	0.64	0.62	0.99	0.73	0.70			
		CD @ 5 %	3.67	4.19	3.19	2.75	1.90	1.82	2.92	2.15	2.08			
		CV (%)	18.34	15.40	13.31	14.67	7.25	7.94	15.02	8.00	8.83			

Values in parentheses are arc sine transformed values ; DAE – Days after emergence

Bt – *Bacillus thuringiensis* Serovar Kurstaki H 3a, 3b, 3c; 5% WP, Halt, 5X10⁷ spore/mg, make - Biostadt

In a column means followed by same alphabet do not differ significantly by CD (P=0.05)

successive seasons viz., Rabi 2014-15 and Rabi 2015-16 on stem borer foliage damage reduction over control was presented in Table 1. The results showed that chlorantraniliprole 18.5% SC was found to be significantly superior at all the intervals of spray sequence over the other treatments and recorded 79.60 per cent mean reduction of foliage damage over untreated control. This was followed by chlorantraniliprole 0.4% GR (72.80%) and spinosad 45% SC (72.63%) in the descending order of their efficacy which were at par. The higher per cent of damage reduction may be due to the application of these chemicals at the initiation of infestation makes borers unable to overcome the impact of early exhaust and to make a heavy population build up. The results pertaining to chlorantraniliprole are in agreement with Anuradha (2013) who reported 1.27 to 2.96 per cent infestation in maize during *Kharif* and 1.06 to 5.60 during *Rabi* in four dosages of coragen. The best treatment in reducing leaf injury (3.43 & 4.23 %) by *C. partellus* was recorded with chlorantraniliprole 18.5 SC during 2012 and 2013 (Ravinder and Jindal, 2015). Significantly less infestation of *C. partellus* (4.5% at 25 DAS and 7.42% at 40 DAS) in maize was observed with the treatment of chlorantraniliprole (Kumar *et al.*, 2015). Yadav (2015) also confirmed the superiority of chlorantraniliprole 20 SC in reducing the borer infestation in maize based on leaf injury rating observed at 25 days after infestation at AICRP centers working on maize during *Kharif*, 2014. The present results about spinosad are in close line with Sohail *et al.* (2002) who showed the efficacy of spinosad to reduce *C. partellus* infestation from 10.72% to almost negligible level (0.74%). Munir Ahmad *et al.* (2010) reported the effectiveness of spinosad 240 EC @ 40 ml acre⁻¹ with reduced borer infestation of 1.2 per cent when compared to the control (38.1%). Similar findings were recorded with Ramesh *et al.* (2012) who reported that the maize stem borer infestation levels were significantly low in spinosad (1.67%). Similar trend was observed with Shahzad *et al.* (2010) on the superiority of spinosad against stem borer of maize.

In the present study, monocrotophos 36% SL was found to be next best with 69.47 per cent reduction in foliage damage and was found to be on par with carbofuran 3G (68.36%) and *B. thuringiensis* 5% WP (57.49%). Similar results were also recorded by Saeed *et al.* (2006) who reported that stem borers were significantly controlled by spraying with monocrotophos. The efficacy of monocrotophos was also supported by Ramesh *et al.* (2012) who reported that bioefficacy of monocrotophos (0.00 to 3.33 %) was found to be on par with that of spinosad (1.67 to 6.7%). The superiority of carbofuran against maize stem borer is in close conformity with the observations of Radha *et al.* (2006) who reported foliar damage per cent of 6.53 and 83.60 per cent reduction in larval population over untreated control in maize with carbofuran. Similar trend was observed with results of Nagarjuna (2005). Similarly, Singh and Sharma (2009) concluded that application of carbofuran 3G (15 kg ha⁻¹) was found to be effective in controlling of *C. partellus* with 8.93 and 7.53 per cent plant infestation during *Kharif* 2006 and 2007, respectively. Further, Saleem *et al.* (2014) and Kulkarni *et al.* (2015) reported that whorl application of carbofuran 3G @ 7.5 kg ha⁻¹ proved to be the best based on leaf injury, pest infestation, stem tunneling and grain yield which performed highly effective and economical in reducing the stem borer damage in maize. Jyothi *et al.* (2016) also reported the superiority of carbofuran with lowest foliage damage of 11.7 per cent and 84.28 per cent mean reduction of stem borer larval population in treated maize plots. In addition to this, the efficacy of granules may be due to the fact that young larvae before gaining entry in to the stem feed in the leaf whorl and get exposed to insecticides placed in the leaf whorls leading to the better efficacy of the insecticide.

In the present study, the biopesticide *B. thuringiensis* was also found to provide significant reduction in the stem borer. The present studies are in close agreement with Kandalkar and Men (2006) who reported that *Bt* spray was found to be the best

Table 3. Effect of biorational insecticides use on the *C. partellus* larval density, exit holes and stem tunneling at harvest in maize during Rabi 2014-15 and 2015-16

T. No.	Insecticide	Dose ha ⁻¹	*No. of larvae plant ⁻¹			*Exit holes plant ⁻¹			† Per cent stem tunneling		
			Rabi 2014-15	Rabi 2015-16	Pooled Mean	Rabi 2014-15	Rabi 2015-16	Pooled Mean	Rabi 2014-15	Rabi 2015-16	Pooled Mean
T ₁	Azadirachtin (10,000 ppm)	1000 ml	1.47 (1.21) ^a	1.07 (1.02) ^{bc}	1.27 (1.13) ^b	1.43 (1.20) ^{bc}	1.00 (1.00) ^b	1.22 (1.10) ^b	9.70 (18.11) ^{bc}	6.43 (14.64) ^{abc}	8.07 (16.49) ^b
T ₂	<i>Beauveria bassiana</i>	10 ⁸ spores	1.40 (1.18) ^a	1.23 (1.10) ^b	1.32 (1.14) ^b	1.70 (1.30) ^b	1.07 (1.03) ^b	1.38 (1.17) ^b	12.27 (20.47) ^b	6.10 (14.11) ^{bcd}	9.18 (17.58) ^b
T ₃	<i>Metarhizium anisopliae</i>	10 ⁸ spores	1.40 (1.18) ^a	1.20 (1.08) ^b	1.30 (1.14) ^b	1.37 (1.17) ^c	1.10 (1.04) ^b	1.23 (1.11) ^b	12.37 (20.60) ^b	6.70 (14.86) ^{ab}	9.53 (17.98) ^b
T ₄	<i>Bacillus thuringiensis</i> (Halt 5%WP)	1 kg	0.53 (0.73) ^{bc}	0.90 (0.93) ^{bc}	0.72 (0.84) ^c	0.93 (0.97) ^d	1.00 (0.99) ^b	0.97 (0.98) ^c	6.93 (15.16) ^{cd}	3.57 (10.83) ^{cde}	5.25 (13.23) ^c
T ₅	Novaluron 10% EC	500 ml	0.73 (0.85) ^b	0.77 (0.87) ^{cd}	0.75 (0.87) ^c	1.00 (0.99) ^d	0.80 (0.89) ^{bc}	0.90 (0.94) ^{cd}	7.47 (15.85) ^{cd}	3.53 (10.64) ^{de}	5.50 (13.51) ^c
T ₆	Spinosad 45% SC	150 ml	0.30 (0.54) ^{cd}	0.33 (0.58) ^{ef}	0.32 (0.56) ^e	0.87 (0.93) ^{de}	0.37 (0.60) ^d	0.62 (0.78) ^{ef}	4.07 (11.52) ^{ef}	0.97 (5.45) ^f	2.52 (9.07) ^{ef}
T ₇	Chlorantraniliprole 18.5% SC	150 ml	0.20 (0.44) ^d	0.17 (0.41) ^f	0.18 (0.42) ^f	0.70 (0.83) ^e	0.33 (0.58) ^d	0.52 (0.72) ^f	2.30 (8.59) ^f	0.93 (5.43) ^f	1.62 (7.17) ^f
T ₈	Chlorantraniliprole 0.4% GR	10 kg	0.50 (0.71) ^{bc}	0.40 (0.62) ^e	0.45 (0.68) ^{de}	0.87 (0.92) ^{de}	0.37 (0.61) ^d	0.62 (0.78) ^{ef}	5.37 (13.13) ^{de}	1.27 (6.14) ^f	3.32 (10.27) ^{de}
T ₉	Carbofuran 3G	10 kg	0.60 (0.76) ^b	0.53 (0.72) ^{de}	0.57 (0.75) ^{cd}	0.87 (0.92) ^{de}	0.57 (0.75) ^{cd}	0.72 (0.84) ^{de}	5.90 (13.80) ^{de}	3.23 (10.35) ^{de}	4.57 (12.23) ^{cd}
T ₁₀	Monocrotophos 36% SL	800 ml	0.50 (0.71) ^{bc}	0.50 (0.71) ^{de}	0.50 (0.70) ^d	.90 0(0.95) ^{de}	0.53 (0.73) ^{cd}	0.72 (0.84) ^{de}	5.17 (13.11) ^{de}	2.73 (9.10) ^{ef}	3.95 (11.38) ^{cde}
T ₁₁	Untreated control	—	1.87 (1.36) ^a	2.27 (1.50) ^a	2.07 (1.44) ^a	2.20 (1.49) ^a	2.50 (1.57) ^a	2.35 (1.53) ^a	20.13 (26.64) ^a	9.73 (18.16) ^a	14.93 (22.74) ^a
		SEM±	0.06	0.06	0.04	0.04	0.08	0.02	1.08	1.32	0.87
		CD @ 5 %	0.19	0.19	0.13	0.13	0.18	0.10	3.17	3.89	2.58
		CV (%)	13.03	13.18	8.47	7.05	12.18	6.47	11.61	21.02	10.99

† Values in parentheses are arc sine transformed values ; * Values in parentheses are square root transformed values

Bt – *Bacillus thuringiensis* Serovar Kurstaki H 3a, 3b, 3c; 5% WP, Halt, 5X10⁷ spore/mg, make - Biostadt

In a column means followed by same alphabet do not differ significantly by CD (P=0.05)

treatment with the least number of dead hearts, leaf injury and maximum grain yield in maize. Novaluron 10% EC and azadirachtin 10000 ppm recorded lower efficacy compared to other biorationals due to the fact that stem borer larvae had the peculiar habit of tunneling of stems. This typical behaviour might have protected the larvae from acquiring the slow acting insecticide coming in contact with insect directly. However, these insecticides showed effectiveness in reducing the foliage damage (45.44% and 38.49%) when compared to untreated control. The present results are in agreement with Ramesh *et al.* (2012) who reported that novaluron (0.01%) and diflubenzuron (0.02%) significantly inferior to other biorational treatments in checking the maize stem borer damage and infestation levels were on par with that of untreated check during *Kharif* 2008 and 2009 at Sikkim.

The entomopathogenic fungi *B. bassiana* and *M. anisopliae* were found to provide unsatisfactory control of *C. partellus* in the present study which is in agreement with the results reported by Spruthi and Shekarappa (2007). However, few earlier reports established the efficacy of these fungi against the maize stem borer under field conditions (Shekarappa, 2001). Selection of potential isolates of the entomopathogenic fungi seems to be a prerequisite to achieve a satisfactory control of *C. partellus*. The type of formulation of biocontrol agent was found to make significant difference in their efficacy. Maniania (1993) found that application of granulated formulation of *B. bassiana* was more effective than spray application at the same concentration, probably owing to its greater persistence.

At both the intervals of observation (30 and 50 DAE) treatments with chlorantraniliprole 18.5% SC, spinosad 45% SC and chlorantraniliprole 0.4% GR were found to be most effective which recorded least per cent dead hearts. Among rest of the treatments *B. thuringiensis* 5% WP (2.42%) was on par with monocrotophos 36% SL (2.81%) at 30 DAE followed by novaluron 10% EC (3.26%) and carbofuran

3 G (3.42%). However, at 50 DAE carbofuran 3 G (5.28%) was found to be on par with monocrotophos 36% SL (5.54%). Treatments including *B. thuringiensis* 5% WP (8.35%) and novaluron 10% EC (8.38%) were next in the order of efficacy. The mean values revealed the superiority of treatments in the order of chlorantraniliprole 18.5% SC (1.71%) > spinosad 45% SC (2.45%) > chlorantraniliprole 0.4% GR (2.99%) > monocrotophos 36% SL (4.18%) > carbofuran 3 G (4.35%) > *B. thuringiensis* 5% WP (5.39%) > novaluron 10% EC (5.82%) > *B. bassiana* (7.66%) > Azadirachtin 10000 ppm (9.14%) > *M. anisopliae* (9.78%) which reiterated the result of two years of experimentation (Table 2). The results are in agreement with Anuradha (2013) who reported 0.0 to 0.68 and 0.0 to 4.31 per cent dead hearts in maize during *kharif* and *rabi*, respectively in four dosages of chlorantraniliprole. The best treatment in reducing dead hearts (3.16 and 3.90%) by *C. partellus* was recorded with chlorantraniliprole 18.5 SC during 2012 and 2013 (Ravinder and Jindal, 2015). Similar trend was observed by Kumar *et al.* (2015) who reported that chlorantraniliprole 18.5 SC was the best with minimum number of dead hearts (2.33 % at 25 DAS and 1.66 % at 40 DAS). The results pertaining to monocrotophos (4.18%) are in agreement with Saeed *et al.* (2006) who reported that stem borer of maize was significantly controlled by monocrotophos. The efficacy of monocrotophos was also supported by Ramesh *et al.* (2012) who reported that monocrotophos (0.05%) significantly reduced the damage of *C. partellus*. The present findings showed that carbofuran is next best (4.35%) and the results are in agreement with Kakar *et al.* (2003) who recorded 2.01 per cent dead hearts. Similar trend was observed with Radha *et al.* (2006) who reported that carbofuran 3G @ 0.3 kg a.i. ha⁻¹ recorded 7.8 per cent dead hearts. Saleem *et al.* (2014) also reported that average dead hearts count for carbofuran 3G was 3.17 per cent. Similar results were also recorded with Kulkarni *et al.* (2015) and Jyothi *et al.* (2016) with respect to carbofuran against maize stem

Table 4. Effect of biorational insecticides use on yield and cost economics for the control of *C. partellus* in Maize

T. No.	Insecticide	Dose ha ⁻¹	Grain Yield (kg ha ⁻¹)			Incremental Yieldover control (kg ha ⁻¹)	Increase in yieldover control (%)	Value of incremental yield (Rs)	*Cost of plant protection (Rs ha ⁻¹)	Net profit (Rs ha ⁻¹)	Incremental B:C ratio
			Rabi 2014-15	Rabi 2015-16	Pooled Mean						
T ₁	Azadirachtin (10,000 ppm)	1000 ml	4708.33 ^{ef}	5734.13 ^{ef}	5221.23 ^f	1248.02	31.43	16224.21	3089.00	13135.21	5.25
T ₂	<i>Beauveria bassiana</i>	10 ⁸ spores	4662.70 ^{ef}	5575.40 ^{ef}	5119.05 ^f	1145.83	28.87	14895.83	3179.00	11716.83	4.69
T ₃	<i>Metarhizium anisopliae</i>	10 ⁸ spores	4513.89 ^f	5039.68 ^g	4776.79 ^f	803.57	20.25	10446.43	2470.00	7976.43	4.23
T ₄	<i>Bacillus thuringiensis</i> (Halt 5%WP)	1 kg	4827.38 ^{de}	5952.38 ^{ef}	5389.88 ^f	1416.67	35.69	18416.67	1786.00	16630.67	10.31
T ₅	Novaluron 10% EC	500 ml	5025.79 ^d	7301.59 ^{cd}	6163.69 ^e	2190.48	55.13	28476.19	4667.00	23809.19	6.10
T ₆	Spinosad 45% SC	150 ml	6944.44 ^a	8928.57 ^{ab}	7936.51 ^{ab}	3963.29	99.77	51522.82	5738.00	45784.82	8.98
T ₇	Chlorantraniliprole 18.5% SC	150 ml	7152.78 ^a	9384.92 ^a	8268.85 ^a	4295.63	108.12	55843.25	4548.00	51295.25	12.28
T ₈	Chlorantraniliprole 0.4% GR	10 kg	6642.86 ^b	8333.33 ^{abc}	7488.10 ^{bc}	3514.88	88.44	45693.45	4788.00	40905.45	9.54
T ₉	Carbofuran 3G	10 kg	5968.25 ^c	7936.51 ^{bcd}	6952.38 ^{cd}	2979.17	75.03	38729.17	3500.00	35229.17	11.07
T ₁₀	Monocrotophos 36% SL	800 ml	5948.41 ^c	6646.83 ^{de}	6297.62 ^{de}	2324.40	58.49	30217.26	1548.00	28669.26	19.52
T ₁₁	Untreated control	—	3720.24 ^g	4226.19 ^g	3973.21 ^g	—	—	—	—	—	—
		SEm±	93.70	447.93	229.86						
		CD @ 5 %	276.41	1321.41	678.10						
		CV%	2.97	11.34	6.48						

Market Price of Maize: Rs. 13/- per kg; Standard spray volume: 500 l/ha; *Labour and sprayer charges including for two sprays
In a column means followed by same alphabet do not differ significantly by CD (P=0.05)

borers. Spray application of *B. thuringiensis* had given satisfactory results (5.39%) in this study as indicated by Deepthi *et al.* (2008) who reported that *B. thuringiensis* (1 g litre⁻¹) was the most effective in reducing dead hearts damage (9.68%) due to stem borer.

The pooled mean larval population of *C. partellus* indicated the lowest population of 0.18 larvae per plant in chlorantraniliprole 18.5% SC with maximum population in untreated check (2.07 larvae plant⁻¹). The overall efficacy of the biorational treatments against the number of exit holes indicated that chlorantraniliprole 18.5% SC was superior over the other biorational treatments and recorded minimum number of exit holes per plant (0.52) followed by spinosad 45% SC and chlorantraniliprole 0.4% GR (0.62) which were on par. The next effective treatments are carbofuran 3G (0.87) and monocrotophos 36% SL (0.72) which were on par with each other. The maximum numbers of exit holes were recorded with azadirachtin 10000 ppm (1.22), *M. anisopliae* (1.23) and *B. bassiana* (1.38) which were on par with each other but were significantly different from control (2.35). The results are in agreement with Lucius and Oniemayin (2011) who reported 1.00 numbers of exit holes when treated with carbofuran compared to control (4.00) and similar trend was observed with Pavani (2011) who reported 0.80 exit holes per plant treated with carbofuran. Jyothi *et al.* (2016) also found minimum number of exit holes caused by stem borer in carbofuran (1.92) and spinosad (3.59) treated maize plots. Chlorantraniliprole 18.5% SC was statistically superior to other treatments with mean lowest tunneling of 1.62 per cent and followed by spinosad 45% SC (2.52%). Next best were chlorantraniliprole 0.4% GR, monocrotophos 36% SL, carbofuran 3G and *B. thuringiensis* 5% WP which recorded 3.32, 3.95, 4.57 and 5.25 per cent, respectively. Maximum stem tunneling was noticed in untreated check with 14.93 per cent (Table 3). The superiority of chlorantraniliprole against maize stem borer is in

accordance with the works of earlier authors who recorded minimum tunnel length (1.94 cm) with chlorantraniliprole (Kumar *et al.*, 2015). The results are also in agreement with Lucius and Oniemayin (2011) who reported 1.0 cm tunnel length when treated with carbofuran compared to control (5.53cm) and the similar trend was observed with Pavani (2011) who reported 0.35 cm tunneling with carbofuran. Jyothi *et al.* (2016) also recorded a tunnel length of 2.73 cm in maize treated with carbofuran which was on par with flubendiamide (2.83 cm) and spinosad (4.13 cm). The results pertaining to *B. thuringiensis* was in close line with Deepthi *et al.* (2008) who reported 15.43 per cent tunneling when treated with *B. thuringiensis* compared to untreated control (22.30%).

Pooled analysis of yield data also confirmed the superiority of all the treatments over untreated control (3973.21 kg ha⁻¹). Superiority of chlorantraniliprole 18.5% SC (8268.85 kg ha⁻¹) followed by spinosad 45% SC (7936.51 kg ha⁻¹) and chlorantraniliprole 0.4% GR (7488.10 kg ha⁻¹) over other inputs was reiterated (Table 4). This finding was in agreement with Ravinder and Jindal (2015) who reported that economic returns on the basis of marketable grain was more in chlorantraniliprole (51.99 q ha⁻¹) in comparison to control (40.44 q ha⁻¹) and biological control plots (46.75 q ha⁻¹). This is also in agreement with earlier report of Kumar *et al.* (2015) who obtained maximum grain yield of 73.33 q ha⁻¹ with chlorantraniliprole. The findings on spinosad corroborate with the results of Ramesh *et al.* (2012) who reported that the highest yield was recorded with spinosad (2365.50 kg ha⁻¹) compared to control (1792.90 kg ha⁻¹). Shahzad *et al.* (2010) reported that spinosad has recorded a grain yield of 5289 kg ha⁻¹ followed by and carbofuran (5215 kg ha⁻¹).

The next best was carbofuran 3G (6952.38 kg ha⁻¹) with 75 per cent increase over control which was followed by monocrotophos 36% SL (6297.62 kg ha⁻¹, 58.5% increase over control) and novaluron

10% EC (6163.69 kg ha⁻¹, 55% increase over control). This is in accordance with Kakar *et al.* (2003) who recorded highest maize grain yield of 4952.33 kg ha⁻¹ with carbofuran. Singh and Sharma (2009) recorded higher grain yield of maize 54.97 and 51.97 (q ha⁻¹) and Jyothi (2016) recorded 35.59 q ha⁻¹ of maize yield (90% yield increase over untreated control) with carbofuran as compared to rest of the treatments also endorses the present findings on carbofuran efficacy. Whereas, Ramesh *et al.* (2012) reported the increase in maize grain yield over untreated check was 38.66 per cent for monocrotophos.

Rest of the treatments in the decreasing order of yield were *B. thuringiensis* (5389.88 kg ha⁻¹ and 36% increase over control), azadirachtin 10000 ppm (5221.23 kg ha⁻¹ and 31.43% increase over control), *B. bassiana* (5119.05 kg ha⁻¹ and 29% increase over control) and *M. anisopliae* (4776.79 kg ha⁻¹, 21% increase over control) and did not vary significantly with each other. Earlier reports by Sharma and Odak (1996) indicated *B. thuringiensis* applied alone provided an increase in yield of 36 per cent in maize over the untreated check. The present studies are also in close agreement with Bhanukiran and Panwar (2005) who reported that *Bt kurstaki* (17.07 q ha⁻¹) and Neemazal – F (5.73 q ha⁻¹) as the next best treatments after endosulfan with respect to yield. While the inferiority of entomopathogenic fungi *B. bassiana* and *M. anisopliae* in terms of maize grain yield confirms the earlier report of Ramesh *et al.* (2012). The report by Deepthi *et al.* (2008) revealed per cent yield increase over untreated control was 23.86% for *M. anisopliae* followed by *B. thuringiensis* (23.47%) also support present findings.

The cost of intervention of different biorational treatments ranged from zero in untreated control to Rs.5738/- per ha in spinosad 45% SC treated plots. Among the biorational treatments maximum IBCR was recorded in chlorantraniliprole 18.5% SC (12.28) which was next best to standard chemical check,

monocrotophos 36% SL (19.52). Proportion of investment to benefit was so close between carbofuran 3G (11.07) and *B. thuringiensis* (10.31). Chlorantraniliprole 0.4% GR (9.54) and spinosad 45% SC (8.98) were next in the order whereas, lowest IBCR was recorded by *M. anisopliae* (4.23). However, rest of the treatments recorded moderate IBCR ranging between 4.69 and 6.10. The highest IBCR was recorded with monocrotophos as the cost is very less compared to the cost of other insecticides. However, highest net returns were recorded by chlorantraniliprole 18.5% SC (Rs. 51,295/-). This was followed by spinosad 45% SC (Rs. 45,784/-) and chlorantraniliprole 0.4% GR (Rs. 40,905/-). Whereas, lower net returns was recorded by *M. anisopliae* (Rs. 7,976/-). However, rest of the treatments recorded net returns ranging from Rs. 11,716/- to Rs. 35,229/- (Table 4). Higher net profits for chlorantraniliprole 18.5% SC in maize has been documented by Kumar *et al.* (2015) which are similar to the present findings.

CONCLUSIONS

In the present study chlorantraniliprole 18.5% SC, spinosad 45% SC and chlorantraniliprole 0.4% GR were found to be the best treatments which could reduce the damage to maize plant by stem borers in terms of less larval density, foliar damage, number of exit holes and stem tunneling. Hence, higher yields were recorded in the plots treated with these biorational insecticides. Apart from their bio-efficacy, the desirable qualities like low mammalian toxicity (Williams *et al.*, 2003); safety to non-target organisms including natural enemies (Anuradha, 2013) and no cross-resistance with conventional insecticides (Ahmed *et al.*, 2002) make these natural insecticides as ideal alternatives for the biorational management of *C. partellus* in maize.

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MICRO LEVEL CLIMATIC CLASSIFICATION OF ANANTHAPURAMU DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Climate is the most important factor which influences selection of crops in a region. Ananthapuramu, being the most drought prone district of Andhra Pradesh needs micro level climatic classification for implementation of contingency plans to combat drought and climate vagaries in the region. Micro level climatic classification of Ananthapuramu district was analysed using meteorological data for 25 years (1988-2012). This analysis has indicated that all the 63 mandals of Ananthapuramu district are having arid climate with moisture index values – 67.4 to – 84.7. The average annual rainfall in the district ranged from 347 mm (CK Palli) to 739 mm (Penukonda). Out of 25 years (1988-2012), complete arid climate was observed in CK Palli, Kuderu, Atmakur, 20-25 years of arid climate was noticed in 41 mandals, 18-20 years of arid climate in 18 mandals and the lowest number of arid years (15) was observed in Penukonda mandal. The trend analysis has indicated that over the last 25 years the aridity is increasing significantly @ \dot{a} = 0.01 in Guntakal, increasing significantly @ \dot{a} = 0.05 in Atmakur, Bommanahal, Kuderu mandals, increasing significantly @ \dot{a} = 0.1 in D Hirehal, Garladinne, Roddam, Nallamada mandals, no change in aridity in Bukkapatnam, Mudigubba, Peddapappur mandals, non-significant increase in arid years was observed in 38 mandals, non-significant decrease in arid years was noticed in 14 mandals.

INTRODUCTION

Ananthapuramu is a drought prone district in rain shadow area of Andhra Pradesh. In this district climate plays major role in selection and success of crops. Climatic classification of a region will be useful to various stakeholders for selection of crops, agricultural planning, drought preparedness, assessment of water demand by different sectors, assessment of climate driven pests/diseases in crops, livestock and humans and also helps in identifying the productivity zones for various crops.

The Planning Commission of India had emphasized the need for district-level plans and the district is the focal unit for several development schemes in the XII five year plan. Rao *et al.*(1972) and Bhattacharjee *et al.* (1982)delineated climatic zones of India using Thornthwaite and Mather (1955) approach. Krishnan (1988) brought the climatic classification of India to district level using the climatic data sets upto 1970. The classification was based on moisture index of Thornthwaite and Mather

(1955), computed using average annual data of rainfall and potential evapotranspiration (PET).

Climate change literature shows enough evidence of rising mean temperatures after 1970 in India. Krishna Kumar *et al.* (2011) observed an increase in mean annual surface air temperature of 0.21°C/10 years after 1970 compared to 0.51°C/100 years during the past century. All-India average monsoon rainfall is found trendless over the period starting from the year 1871, though significant spatial variations are found at division level. At macro level, rising temperature along with no significant trend in monsoon rainfall may cause aridity to rise. However, if we examine at micro level such as mandal, there may be different trend. As there is greater variability, especially in rainfall pattern, within the district, it is advisable to conduct micro-regional analysis wherever the data is available at sub-district level. Ananthapuramu, being the most drought prone district of Andhra Pradesh needs micro level/mandal level climatic classification for implementation of

various schemes to combat drought. Keeping this in view, micro level climatic classification was attempted using latest available climatic data.

MATERIAL AND METHODS

Mandal wise daily rainfall data of all the 63 mandals of Ananthapuramu district for 25 years (1988-2012) was collected from Directorate of Economics and Statistics, Govt. of Andhra Pradesh. Daily weather data recorded at Agricultural Research Station(ARS), Ananthapuramu from 1988 to 2012 was used for calculation of potential evapotranspiration (PET) by following FAO Penman – Monteith method using PET calculator software developed by All India Coordinated Research Project(AICRP) on Agrometeorology, CRIDA, Hyderabad. The mandal wise daily rainfall and daily PET were converted to annual rainfall and PET using Weather Cock 1.5 software developed by AICRP on Agrometeorology, CRIDA, Hyderabad. The annual rainfall and PET values thus obtained were utilized for calculation of mandal wise annual moisture index (MI) as given by Thornthwaite and Mather (1955) and simplified by Venkataraman and Krishnan (1992) using the formula $MI = \left[\frac{P - PET}{PET} \right] \times 100$, where MI is the moisture index, P the annual rainfall and PET is the annual potential evapotranspiration. The overall climate prevailing in each mandal during the study period was assessed by calculating moisture index (MI) based on the average annual rainfall and the average annual potential evapotranspiration. Further, the climate prevailing in each mandal during the study period was assessed as following:

Value of MI	Climatic Zone
< - 79.9	Super Arid
-73.3 to - 79.8	Hyper Arid
-66.7 to - 73.2	Arid
-66.6 to - 33.3	Semi-arid
-33.3 to 0	Dry sub-humid
0 to + 20	Moist sub-humid
+20.1 to + 99.9	Humid
100 or more	Per-humid

To know the climatic variability, the trend of the moisture index over the last 25 years was calculated by following Mann-Kendall test. An Excel template application MAKESENS Version 1.0 (Salmi *et al.*, 2002) was used for the Mann–Kendall trend analysis.

RESULTS AND DISCUSSION

The average annual rainfall in various mandals of Ananthapuramu district ranged from 347 mm (CK Palli) to 739 mm (Penukonda) (Fig. 1) and the average annual PET was 2264 mm. The climatic analysis has revealed that all the 63 mandals of Ananthapuramu district are having arid climate with MI values -67.4 to – 84.7 (Table 1) (Fig.2). Lower value of MI indicates that the rainfall received is not sufficient to meet the potential evapotranspiration demand in that mandal. The MI value also indicates the degree of aridity. Lesser the MI value, higher will be the aridity in that particular mandal. Lowest MI (-84.7) and highest aridity was observed in CK Palli followed by Kuderu, Kambadur, Yellanur, Garladinne, Atmakur, Pedavadagur, Peddapappur mandals. Out of 25 years (1988-2012), complete arid climate was observed in CK Palli, Kuderu, Atmakur, 20-25 years of arid climate was noticed in 41 mandals, 18-20 years of arid climate in 18 mandals and the lowest no.of arid years (15) were observed in Penukonda mandal (Fig.3).

Mandal wise moisture index (MI) which is an indication of intensity of arid climate was analyzed using Mann-Kendall test for the period 1988 to 2012. The trend analysis has indicated that magnitude of aridity or arid climate (as indicated moisture index value) is increasing significantly @ $\alpha = 0.01$ in Guntakal, increasing significantly @ $\alpha = 0.05$ in Atmakur, Bommanahal, Kuderu, increasing significantly @ $\alpha = 0.1$ in D Hirehal, Garladinne, Roddam, Nallamada, no change in aridity was observed inBukkapatnam, Mudigubba, Peddapappur, non-significant increase in arid years observed in 38 mandals, non-significant decrease in arid years noticed in 14 mandals (Table 2).

MICRO LEVEL CLIMATIC CLASSIFICATION FOR ANANTHAPURAMU DISTRICT

Fluctuations in climate over a region provide a valuable input to study the changes that affecting crop productivity. In a study on revised

climatic classification of India at district level, Raju *et al.*(2013) reported that arid climate prevailed in Ananthapuramu district during the period 1971-2005.

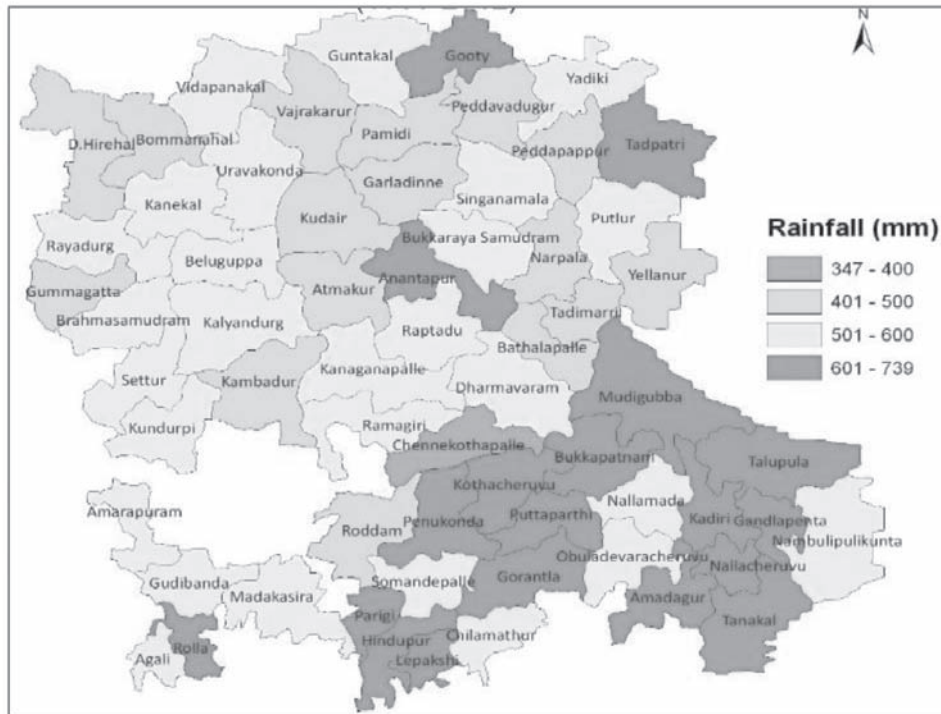


Fig. 1. Mean Annual Rainfall (mm) in Ananthapuramu District (1988-2012)

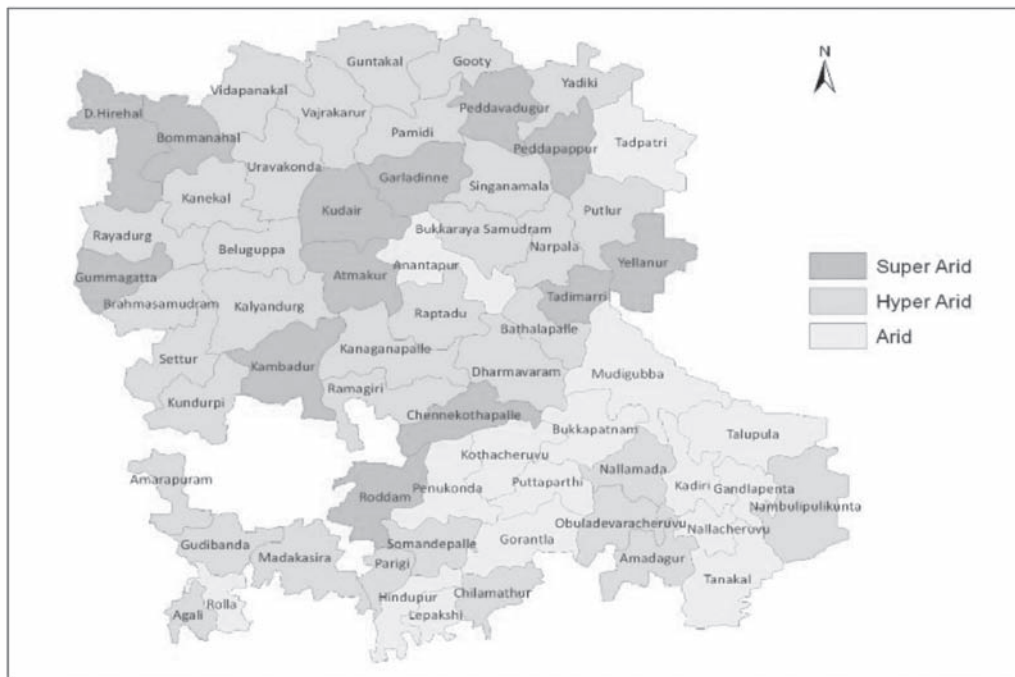


Fig. 2. Mandal wise climatic classification of Ananthapuramu District (1988-2012)

Table 1. Mandal wise mean annual rainfall (mm), Moisture Index (MI), Climate and years with semi-arid and arid climate in Ananthapuramu district (1988-2012)

Name of the mandal	Mean Annual rainfall (mm)	Mean MI	Climate	No.of years with	
				Semi-arid climate	Arid climate
Agali	586.9	-74.1	Arid	4	21
Amadagur	603.0	-73.4	Arid	5	20
Amarapuram	543.1	-76.0	Arid	5	20
Anantapur	608.2	-73.1	Arid	5	21
Atmakur	440.0	-80.6	Arid	0	25
Bathalapalli	491.4	-78.3	Arid	1	24
Beluguppa	504.7	-77.7	Arid	4	21
Bommanahal	474.3	-79.0	Arid	1	24
Brahmasamudram	500.9	-77.9	Arid	2	24
Bukkapatnam	712.6	-68.5	Arid	8	18
Bukkarayasamudram	553.1	-75.6	Arid	4	21
CK Palli	347.0	-84.7	Arid	0	25
Chilamuttur	545.9	-75.9	Arid	5	21
D Hirehal	475.6	-79.0	Arid	2	23
Dharmavaram	598.7	-73.5	Arid	6	20
Gandlapenta	629.2	-72.2	Arid	7	18
Garladinne	431.7	-80.9	Arid	2	23
Gooty	606.9	-73.2	Arid	7	19
Gorantla	624.8	-72.4	Arid	7	18
Gudibanda	503.9	-77.7	Arid	2	23
Gummagatta	474.9	-79.0	Arid	1	24
Guntakal	589.7	-73.9	Arid	5	20
Hindupur	676.7	-70.1	Arid	9	17
Kadiri	728.8	-67.8	Arid	9	16
Kalyanadurgam	569.3	-74.8	Arid	5	20
Kambadur	429.4	-81.0	Arid	1	24
Kanaganapalli	502.9	-77.8	Arid	3	23
Kanekal	539.6	-76.2	Arid	4	21
Kothacheruvu	658.9	-70.9	Arid	10	16
Kuderu	414.5	-81.7	Arid	0	25
Kundurpi	505.4	-77.7	Arid	3	22

MICRO LEVEL CLIMATIC CLASSIFICATION FOR ANANTHAPURAMU DISTRICT

Contd..

Name of the mandal	Mean Annual rainfall (mm)	Mean MI	Climate	No.of years with	
				Semi-arid climate	Arid climate
Lepakshi	650.4	-71.3	Arid	7	19
Madakasira	587.7	-74.0	Arid	7	19
Mudigubba	721.2	-68.1	Arid	10	16
Nallacheruvu	608.0	-73.1	Arid	6	19
Nallamada	571.3	-74.8	Arid	5	21
NP Kunta	584.0	-74.2	Arid	4	21
Narpala	481.6	-78.7	Arid	2	24
OD Cheruvu	564.3	-75.1	Arid	3	22
Pamidi	489.8	-78.4	Arid	2	23
Parigi	600.3	-73.5	Arid	4	21
Pedavadaguru	442.1	-80.5	Arid	2	23
Peddapappur	453.3	-80.0	Arid	2	24
Penukonda	738.7	-67.4	Arid	11	15
Putlur	583.1	-74.2	Arid	5	21
Puttaparathi	636.6	-71.9	Arid	7	19
Ramagiri	561.4	-75.2	Arid	4	21
Rapthadu	586.5	-74.1	Arid	5	21
Rayadurgam	583.4	-74.2	Arid	6	20
Roddam	475.2	-79.0	Arid	4	22
Rolla	611.0	-73.0	Arid	6	20
Settur	520.0	-77.0	Arid	3	22
Singanamala	518.5	-77.1	Arid	4	22
Somandepalli	593.5	-73.8	Arid	8	18
Tadimarri	470.9	-79.2	Arid	2	24
Tadipatri	630.3	-72.2	Arid	4	21
Talupula	624.5	-72.4	Arid	7	18
Tanakal	622.6	-72.5	Arid	6	20
Uravakonda	569.9	-74.8	Arid	4	21
Vajrakarur	484.4	-78.6	Arid	3	22
Vidapanakal	580.0	-74.4	Arid	5	20
Yadiki	500.9	-77.9	Arid	5	21
Yellanur	430.3	-81.0	Arid	1	24
Ananthapuramu district	554.7	-75.5	Arid	3	22

Table 2. Trend of arid climatic years during 1988-2012 in various mandals of Ananthapuramu District

Trend of Arid climatic years	Name of the Mandal
Increasing significantly @ $\alpha = 0.01$	Guntakal (1)
Increasing significantly @ $\alpha = 0.05$	Atmakur, Bommanahal and Kuderu (3)
Increasing significantly @ $\alpha = 0.1$	D Hirehal, Garladinne, Nallamada and Roddam (4)
Increasing but Non-significant	Agali, Kalyanadurgam, Settur, Amarapuram, Kanekal, Somandepalli, Anantapur, Kothacheruvu, Tadimarri, Bathalapalli, Lepakshi, Talupula, Beluguppa, Nallacheruvu, Tanakal, Bukkarayasamudram, Narpala, Uravakonda, Chennekothapalli, Pamidi, Vajrakarur, Chilamuttur, Pedavadaguru, Vidapanakal, Dharmavaram, Penukonda, Yadiki, Gandlapenta, Putlur, Yellanur, Gooty, Puttaparthi, Gorantla, Ramagiri, Gudibanda, Raphthadu, Kadiri and Rayadurgam (38)
Decreasing but Non-significant	Amadagur, Brahmasamudram, Gummagatta, Hindupur, Kambadur, Kanaganapalli, Kundurpi, Madakasira, Nambulipulikunta, Obuladevara Cheruvu, Parigi, Rolla, Singanamala and Tadipatri (14)
No Trend	Bukkapatnam, Mudigubba and Peddapappur (3)

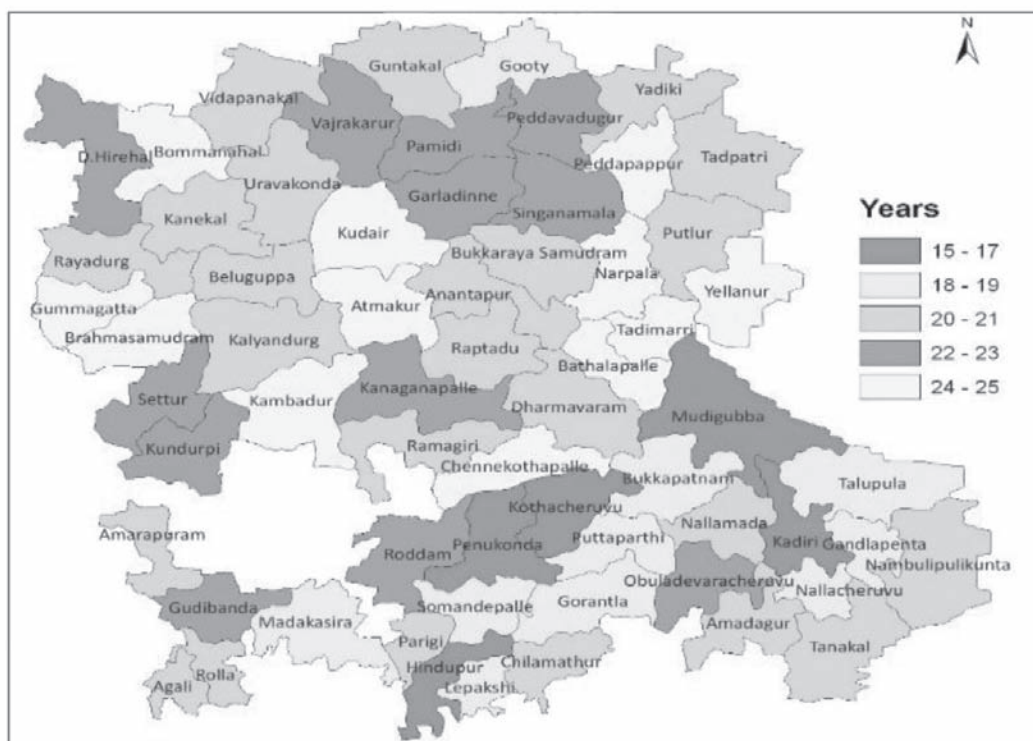


Fig. 3. Mandal wise no. of years with arid climate in Ananthapuramu District (1988-2012)

They opined that there is a need to revise climatic classification at least once in 30 years; may be more frequently in future since more warming trends have been projected for future. Such an exercise may help in knowing the spatial shifts of climatic zones, which has bigger implications for crop planning, water resources assessment and launching of special schemes on drought including disaster management.

CONCLUSION

Based on the investigation it could be stated that there is an immediate need to concentrate on contingency crop planning and drought preparedness in Guntakal, Atmakur, Bommanahal, Kuderu, D Hirehal, Garladinne, Nallamada, Roddam, Pedavadagur, Peddapappur, CK Palli, Yellanur mandals of Ananthapuramu district. Also, “weather indices” shall be developed for crops rather than “climate indices” for successful growth of crops as climate indices are ‘annual’ indices and do not fit for crop health management thereby yields.

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COMPARISON OF EXTRACTANTS TO ASSESS POTASSIUM AVAILABILITY IN SOILS OF MAJOR CROPPING SYSTEMS IN KURNOOL DISTRICT

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ABSTRACT

Sixty representative surface soil samples (0-15 cm) were collected during 2015-16 from five major cropping systems (*viz.*, rice-rice, fallow-bengalgram, groundnut-groundnut maize-maize, rice-maize/mustard) covering 13 mandals in Kurnool district to compare the extractants to assess potassium availability in relation with K uptake studies in soils of major cropping systems. The soils under study were moderately coarse to fine in texture neutral to slightly alkaline, non saline and non-calcareous. Among the extractants tried, the relative efficiency of K releasing extractants were in the order: 1 N HNO₃ > Mehlich-3 > N .N NH₄OAc > 0.01M CaCl₂ > distilled water. Highest amount of potassium was extracted in maize-maize cropping system and lowest in groundnut-groundnut cropping system with all the extractants. Relative efficiency of extractants also evaluated with reference to dry matter yield, content and uptake of K by maize crop. All these K extractants were positively correlated with each other, though these extractants removed different quantities of K. The plant parameters *i.e.* dry matter; K content and K uptake of maize crop were highest in maize-maize cropping system and lowest in groundnut –groundnut cropping system with the all extractants. Among the 5 extractants tried, 1N HNO₃ showed the highest significant and positive correlation with yield (0.897^{**}), content (0.890^{**}) and uptake (0.933^{**}) of potassium of maize crop followed by N NH₄OAc and Mehlich-3. The highest positive and significant correlation of plant parameters was found with N N NH₄OAc followed by 1 N HNO₃ in maize-maize cropping system, fallow-bengal gram cropping system and groundnut-groundnut cropping system, whereas, incase of rice-maize/mustard cropping system and rice-rice cropping system 1 N HNO₃ showed the highest correlation with plant parameters followed by N N NH₄OAc. A close observation of the data indicated that 1 N HNO₃ can be used along with N N NH₄OAc for assessing available potassium in soils of major cropping systems in Kurnool district.

INTRODUCTION

Potassium is one of major and essential plant nutrients has instrumental role in plant nutrition and physiology. Many chemical methods such as 1N NH₄OAc, Mehlich-3, salts and dilute acids were studied by researchers for evaluation of available potassium (K) in soils (Srinivasa Rao and Takkar, 1997 and Mehta *et al.*, 2001). Though, N N NH₄OAc is a better extractant for assessing available K status of soils has been reported by number of workers, the results obtained under AICRP on cropping systems indicated that the response to applied K have been observed in soils analyzing high in available K. Potassic fertilizer scheduling is done on the basis of available K in soil measured by N N NH₄OAc. A pot culture study was conducted to quantify the role of potassium required for plant growth using maize as test crop. To evaluate the relative efficiency of extractants with reference to dry

matter yield, K content and uptake of K. The role of potassium may vary from crop to crop and soil to soil, mainly due to existence of variation in agro climatic zones and nature of soil minerals supplying the nutrient. The information exclusively on soils under different cropping systems is in adequate. The present investigation was conducted on major cropping systems in Kurnool district to study the K status and to evaluate the relative efficiency of an extractant for available potassium in the soil for supplementing the crop with proper amounts of fertilizer K.

MATERIAL AND METHODS

The study was undertaken in the Department of Soil Science and Agricultural Chemistry, Agricultural College, Mahanandi during the year 2015-16. Sixty representative surface soil samples (0-15 cm) in bulk were collected from five cropping

systems (black and red soils viz. rice-rice, rice-maize/mustard, maize-maize, fallow-bengalgram, groundnut-groundnut in Kurnool district. Soil samples were extracted with neutral normal ammonium acetate for K status. Based on K content 30 soil samples are selected for K studies. The soil samples collected were air dried and passed through 2 mm sieve. Each sample was then sub-sampled, by quartering and finally a representative soil sample was preserved in a polythene bag for laboratory analysis. The selected soils were analyzed for their initial soil properties and potassium release characteristics. The particle size analysis was carried out by Bouyoucous hydrometer method. The pH and EC were determined in 1:2 soils, water suspension using pH meter and EC meter. The free CaCO₃ content was determined as per procedure given by Piper. The texture of the soils has ranged from sandy loam to clay and moderately coarse to fine texture. Water soluble potassium was determined in 1:5 soil: water extract, after 5 minutes equilibration and potassium in the aliquot was determined by flame photometer. Potassium was extracted in the *NN* NH₄OAc (soil: extractant ratio of 1:5 equilibrating for 5 min) and the potassium in the aliquot was determined by flame photometer. The potassium was estimated by boiling the soil with 1*N* HNO₃ (soil: acid ratio 1:10) for 10 minutes and the K content in the aliquot was determined by flame photometer. Potassium was extracted with 0.01 M calcium chloride (soil: extractant ratio of 1:10, equilibrating for 30 min) and the potassium in the aliquot was determined by flame photometer (Srinivasa Rao and Takkar, 1997). Potassium was extracted with 0.02 M CH₃COOH, 0.25 M NH₄NO₃, and 0.015 M NH₄F, 0.013 M HNO₃ and 0.001M EDTA (Mehlich-3) maintaining 1:10 soil: extractant ratio equilibrating for 5 minutes. The potassium in the extract was determined by flame photometer. A pot

culture experiment was conducted (by using 5 Kg each of 2.0 mm sieved soil of different cropping system were taken in earthen pots) and P-3396 maize hybrid was used as test crop. A common recommended dose of nitrogen and phosphorous applied to all the treatments as per recommended dose 250 N and 60 Kg ha⁻¹ P₂O₅, respectively. Potassium was not applied to crop. The maize seedlings @ three per pot were sown in each pot. Two plants were removed at 10 DAS and incorporated in same pot so that only one plant was maintained in each pot and the crop is harvested at 60 DAS. Plant samples collected at 60 DAS were processed and subjected to the tri acid digestion mixture of HNO₃: HClO₄: H₂SO₄ (9:4:1) and the K content was determined by using flame photometer. The dry matter and K content were determined. The potassium uptake was calculated using the following formula and expressed in g pot⁻¹.

$$\text{Nutrient uptake (g pot}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter production (g pot}^{-1}\text{)}}{100}$$

RESULTS AND DISCUSSION

The pH of soils used in the study varied from 6.9 in red soils of Yembavi in groundnut-groundnut cropping system to 8.4 in black soils of Bheemunipadu of rice-mustard cropping system (Table 1), indicating that soils under investigation were neutral to slightly alkaline. The electrical conductivity of soils ranged from 0.10 dSm⁻¹ in red soils of Yembavi of groundnut-groundnut cropping system to 0.69 dSm⁻¹ in black soils of Venkateswarapuram in fallow bengalgram cropping system with a mean value of 0.31 dSm⁻¹, soils were non-saline and non-calcareous. The texture of the soils varied from moderately coarse to fine in texture i.e. sandy loam to clay (Table 1).

Distilled water extractable K

The highest mean distilled water extractable potassium was observed in rice-mustard/maize cropping system (17 mg kg⁻¹) followed by maize-maize cropping system (16 mg kg⁻¹), rice-rice cropping system (13 mg kg⁻¹), fallow bengalgram cropping system (9 mg kg⁻¹) and lowest in groundnut-groundnut cropping system (7 mg kg⁻¹) (Table 2). The distilled water extracted lower amounts of K than that of the other extractants because distilled water is the softest extractant possible (Rathore *et al.*, 2000). This was in conformity with the results of Siva Prasad (2014).

0.01 M CaCl₂ extractable K

The mean value of 0.01 M CaCl₂ extractable potassium was higher in rice-rice cropping system (50 mg kg⁻¹) followed by maize-maize cropping system (39 mg kg⁻¹), rice-mustard/maize cropping system (38 mg kg⁻¹), fallow bengal gram cropping system (33 mg kg⁻¹) and the lower values were noticed in groundnut-groundnut cropping system (20 mg kg⁻¹) (Table 2).

The potassium extracted with 0.01 M CaCl₂ is lower than N.N.NH₄OAc and high compared to distilled water. Generally soils with high clay content show high K release with dilute salt solution. Similar findings were reported by Srinivasa Rao and Takkar (1997). Lakshminarayana *et al.* (2011) also found lowest amount of available K with 0.01 M CaCl₂ than that of 1 N HNO₃ and N.N NH₄OAc, which might be due to its low solubilization effect on non exchangeable and lattice K forms. Similar reports were also made by Bedi *et al.* (2002).

N.N. NH₄OAc extractable K

Ammonium acetate was the most commonly used extractant, which extracts, both exchangeable and water soluble K. The highest mean available form

of potassium was higher in maize-maize cropping system (357 mg kg⁻¹) followed by fallow bengal gram cropping system (292 mg kg⁻¹), rice-mustard/maize cropping system (269 mg kg⁻¹), rice-rice cropping system (182 mg kg⁻¹) while the lower value were found in groundnut-groundnut cropping system (153 mg kg⁻¹) (Table 2).

Mehlich-3 extractable-K

The mean value of Mehlich-3 extractable potassium was higher in maize-maize cropping system (403 mg kg⁻¹) followed by fallow bengal gram system (337 mg kg⁻¹), rice-mustard/maize cropping system (300 mg kg⁻¹) and rice-rice cropping system (238 mg kg⁻¹) and the lower value were recorded in groundnut-groundnut cropping system (201 mg kg⁻¹) (Table 2).

1 N Boiling HNO₃ extractable K

The mean value of 1 N Boiling HNO₃ extractable potassium was found to be higher in maize-maize cropping system (770 mg kg⁻¹) followed by fallow bengal gram system (639 mg kg⁻¹), rice-mustard/maize cropping system (534 mg kg⁻¹), rice-rice cropping system (417 mg kg⁻¹) and lower values were noticed in groundnut-groundnut cropping system (358 mg kg⁻¹) (Table 2). Among all the extractants, significantly higher amounts of K were extracted by 1 N HNO₃ because in addition to exchangeable K, some of the non-exchangeable K is brought into solution by the breakdown of primary and secondary clay minerals (Pati Ram and Prasad, 1983). The mineral acids release more K than organic acids since mineral acids add higher H⁺ activity for the same concentration and were obviously more effective in solubilising potassium from minerals (Ghosh, 1985). Similar findings were also reported by Singh *et al.* (1992); Kalyani (2012). On the basis of extractability of potassium the extractants were in the order of r; 1 N HNO₃ > Mehlich-3 > N.N

$\text{NH}_4\text{OAc} > 0.01\text{M CaCl}_2 > \text{distilled water}$. Higher amounts of potassium were extracted in maize-maize cropping system while the lower amounts were recorded in lowest in groundnut-groundnut cropping system with all the extractants.

Potassium study by pot culture studies

The plant parameters *i.e.* dry matter, K content and K uptake of maize crop were highest in Srinagaram village of maize-maize cropping system and lowest in Balapala palli village of groundnut – groundnut cropping system. A wide variation in plant parameters in different soils was observed due to the variation in potassium supplying power of soils (Nath and Dey, 1982) and also observed the variation in dry matter yields in the alluvial soils of Assam and in *Aridisols* of Rajasthan (Sharma and Swami, 2000). The value of dry matter varied from 9.63 (Balapalapalli) to 44.26 g pot⁻¹ (Srinagaram) with a mean value of 26.35 g pot⁻¹ (Table 3). The percent K content ranged from 1.35 per cent in Balapalapalli to 3.50 per cent in Srinagaram with a average value of 2.30 percent. Similarly the K uptake was ranged from 0.13 g pot⁻¹ in Balapalapalli to 1.55 g pot⁻¹ in Srinagaram with a mean of 0.65 g pot⁻¹.

Correlation coefficients (r) among the extractants of potassium

The data presented in the Table 4 shows that the variability in the amount of potassium extracted between these methods is attributed to the concentration of extractant. These extractants desorbed solution, exchangeable, non-exchangeable and some of the lattice K. The correlation coefficients between K extracted by these chemical methods are shown in the Table 4. All these K extractants were positively correlated with each other, though these extractants removed different quantities of K which indicated that these methods can be used for

assessment of availability of K in present investigated soils and also amount of potassium extracted were comparable. Similar reports were made by Bedi *et al.* (2002).

Correlation co-efficient (r) between extracting agents and plant parameters

Among the 5 extractants tried, 1N HNO_3 showed maximum positive and significant correlation with yield, content and uptake of potassium of maize crop followed by N NH_4OAc and Mehlich-3 (Table 5). The relative efficiency of the extractants among the different cropping systems was studied by working out correlation co-efficient between extractants and plant parameters and data was presented in the Tables 6 to 10. The data revealed that the higher significant and positive correlation of plant parameters was found with N N NH_4OAc followed by 1 N HNO_3 in maize-maize cropping system, fallow-Bengal gram cropping system and groundnut-groundnut cropping system. In case of rice-maize/mustard cropping system and rice-rice cropping system, 1 N HNO_3 showed the higher positive and significant correlation with plant parameters followed by N N NH_4OAc . These results are in conformity with the findings of Liangxue and Bates (1990). Siva Prasad (2014) also reported that among the eight extractants tried, 1N HNO_3 showed high positive correlation with dry matter yields and uptake of shoot and whole plant and also showed positively significant correlation with the shoot K content of bajra crop in Neubauer's rapid seedling technique followed by Mehlich-3 and N NH_4OAc . Similar reports were given by Swamanna (2015). A close observation of the data indicated that 1 N HNO_3 can be used along with N N NH_4OAc for assessing available potassium in soils of major cropping systems in Kurnool district.

Table 1. Physico-chemical properties of experimental soils

S. No	Village Name	Cropping system	GPS coordinates	pH	EC (dS m ⁻¹)	Ca CO ₃ (%)	O.C (mg)	Texture
1	RARS,Nandyal	Rice-rice	N:15°28.500 E:078°30.159	8.2	0.22	0.68	0.47	Clay
2	Battaluru	Rice-rice	N:15°14.102 E:078°28.127	8.1	0.46	0.49	0.43	Silty loam
3	Nallagatta	Rice-rice	N:15°13.219 E:078°30.157	7.9	0.20	2.27	0.44	Silty clay loam
4	Kaminenipalli	Rice-rice	N:15°23.479 E:078°33.197	7.5	0.18	0.22	0.27	Loam
5	Yerragudinna	Rice-rice	N:15°11.186 E:078°31.912	7.4	0.21	2.72	0.36	Silty clay loam
6	M.C. farm	Rice-rice	N:15°25.577 E:078°22.563	7.3	0.32	1.58	0.46	Sandy loam
7	Srinagaram	Maize-maize	N:15°27.141 E:078°33.734	8.3	0.68	0.22	0.44	Sandy clay loam
8	Tamadapalli	Maize-maize	N:15°28.524 E:078°32.900	8.1	0.27	0.22	0.55	Silty clay loam
9	Velpanuru	Maize-maize	N:15°42.042 E:078°31.273	8.2	0.20	1.36	0.46	Sandy clay
10	Mahanandi	Maize-maize	N:15°26.212 E:078°37.344	7.9	0.20	1.59	0.45	Silty clay loam
11	Nallakalva	Maize-maize	N:15°52.568 E:078°41.425	7.2	0.17	2.04	0.34	Loam
12	M.C.farm	Maize-maize	N:15°28.416 E:078°23.492	7.4	0.18	1.45	0.48	Sandy loam
13	Kanala	Rice-mustard	N:15°25.814 E:078°27.581	8.2	0.19	0.90	0.39	Silty clay loam
14	Bhemunipadu	Rice-mustard	N:15°23.332 E:078°31.676	8.4	0.55	2.07	0.33	Sandy clay loam
15	Bollavaram	Rice-maize	N:15°27.512 E:078°24.421	7.9	0.30	2.32	0.41	Sandy clay loam
16	Rythunagaram	Rice-mustard	N:15°28.406 E:078°32.475	7.3	0.57	0.45	0.43	Loam
17	Ayyavarikoduru	Rice-maize	N:15°31.234 E:078°31.68	7.2	0.22	1.81	0.44	Sandy clay loam
18	Gajulapalli	Rice-maize	N:15°24.263 E:078°38.046	7.5	0.10	2.12	0.41	Sandy clay loam
19	RARS,Nandyal	Fallow bengalgram	N:15°28.150 E:078°30.229	8.1	0.68	2.04	0.50	Silty clay loam
20	Venkateswarapuram	Fallow bengalgram	N:15°32.340 E:078°22.563	8.3	0.69	1.68	0.51	Silty clay loam

Contd...

Contd...

S. No	Village Name	Cropping system	GPS coordinates	pH	EC (dS m ⁻¹)	Ca CO ₃ (%)	O.C (mg)	Texture
21	Neravada	Fallow bengalgram	N:15°33.752 E:078°24.793	8.0	0.17	1.13	0.48	Silty loam
22	Balapanuru	Fallow bengalgram	N:15°29.918 E:078°20.197	8.2	0.26	1.81	0.47	Silty clay loam
23	Kouluru	Fallow bengalgram	N:15°33.334 E:078°25.194	8.0	0.21	0.90	0.53	Silty clay loam
24	Boyirevula	Fallow bengalgram	N:15°41.097 E:078°33.616	7.8	0.31	0.18	0.34	Sandy clay loam
25	M.C.farm	Groundnut-groundnut	N:15°53.121 E:078°33.374	7.4	0.11.	0.45	0.27	Sandy loam
26	Shankarapalli	Groundnut-groundnut	N:15°52.672 E:077°62.472	7.1	0.19	0.90	0.27	Sandy loam
27	Muddaram	Groundnut-groundnut	N:15°53.451 E:077°66.537	7.2	0.14	0.22	0.21	Sandy loam
28	Balapuram	Groundnut-groundnut	N:15°54.326 E:077°63.612	7.1	0.26	5.21	0.42	Loam
29	Balalalapalli	Groundnut-groundnut	N:15°55.251 E:077°71.691	7.2	0.66	0.22	0.34	Sandy loam
30	Yembavi	Groundnut-groundnut	N:15°48.780 E:078°21.420	6.9	0.10	2.72	0.24	Sandy loam
Mean					0.31	2.13	0.40	

COMPARISON OF SOIL EXTRACTANTS TO ASSESS POTASSIUM AVAILABILITY

Table 2. Efficiency of different extracting agents of potassium in soils of major cropping systems in Kurnool district (mg kg⁻¹ soil)

S. No	Village name	Cropping system	Distilled water extractable K	0.01M CaCl ₂ extractable K	NN NH ₄ OAC extractable K	Mehlich 3 extractable K	1N boiling HNO ₃ extractable K
1	RARS, Nandyal	R-R	12	51	225	353	570
2	Battaluru	R-R	12	31	190	210	387
3	Nallagatla	R-R	16	65	183	256	428
4	Kaminenipalli	R-R	11	34	82	106	210
5	Yerragudidinna	R-R	10	46	130	184	270
6	M.C. farm	R-R	17	70	279	320	635
		Mean	13	50	182	238	417
7	Srinagaram	M-M	22	40	779	820	1586
8	Tamadapalli	M-M	15	45	338	394	730
9	Velpanuru	M-M	14	38	355	376	852
10	Mahanandi	M-M	13	36	215	265	416
11	Nallakalva	M-M	9	25	131	172	331
12	M.C.farm	M-M	20	48	326	392	703
		Mean	16	39	357	403	770
13	Kanala	R-MU	9	18	246	268	364
14	Bhemunipadu	R-MU	13	37	131	124	268
15	Rythunagaram	R-MU	21	48	357	404	758
16	Bollavaram	R-MA	11	26	371	415	820
17	Ayyavarikoduru	R-MA	18	40	206	221	328
18	Gajulapalli	R-MA	28	57	305	365	668
		Mean	17	38	269	300	534
19	RARS, Nandyal	FB	8	36	261	303	623
20	Venkateswarwपुरam	FB	11	45	362	402	853
21	Neravada	FB	6	31	210	278	453
22	Balapanuru	FB	10	26	326	390	680
23	Kouluru	FB	13	38	475	515	960
24	Boyirevula	FB	5	23	117	136	267
		Mean	9	33	292	337	639
25	M.C.farm	GN-GN	8	18	201	264	421
26	Shankarapalli	GN-GN	10	23	203	243	436
27	Muddaram	GN-GN	6	15	71.5	101	189
28	Balapuram	GN-GN	7	24	301	375	741
29	Balalpalalli	GN-GN	8	17	57.5	102	166
30	Yembavi	GN-GN	5	25	81	119	193
		Mean	7	20	153	201	358

R- R: rice-rice, M-M: maize-maize, R-MA: rice-maize, R-MU: rice-mustard, FB: fallowbengalgram, GN-GN:groundnut-groundnut

Table 3. Dry matter, K content and K uptake of maize crop in studied soils

S.No	Village Name	Drymatter (g pot ⁻¹)	K content (%)	K uptake (g pot ⁻¹)
1	RARS, Nandyal rice	28.91	2.20	0.64
2	Battaluru	27.86	2.03	0.57
3	Nallagatla	25.98	2.08	0.54
4	Kaminenipalli	11.74	1.45	0.17
5	Yerragudidinna	23.99	1.95	0.47
6	M.C. farm, rice	32.07	2.59	0.83
7	Srinagaram	44.26	3.50	1.55
8	Tamadapalli	34.89	2.70	0.94
9	Velpanuru	35.98	3.25	1.17
10	Mahanandi	25.05	2.35	0.59
11	Nallakalva	21.76	1.91	0.42
12	M.C. farm, maize	33.35	2.70	0.90
13	Kanala	26.77	2.46	0.66
14	Bhemunipadu	18.37	1.73	0.32
15	Rythunagaram	33.36	3.21	1.07
16	Bollavaram	36.06	3.20	1.15
17	Ayyavarikoduru	23.19	2.03	0.47
18	Gajulapalli	29.47	2.33	0.69
19	RARS,Nandyal Bengalgram	28.42	2.35	0.67
20	Venkateswarwपुरam	32.37	2.95	0.95
21	Neravada	24.99	2.26	0.56
22	Balapanuru	31.36	2.45	0.77
23	Kouluru	38.16	2.75	1.05
24	Boyirevula	14.37	1.71	0.02
25	M.C.farm, groundnut	22.84	2.15	0.49
26	Shankarapalli	24.80	2.24	0.56
27	Muddaram	10.52	1.41	0.15
28	Balapuram	28.93	2.40	0.69
29	Balapalapalli	9.63	1.35	0.13
30	Yembavi	11.17	1.40	0.16
	Mean	26.35	2.30	0.65

COMPARISON OF SOIL EXTRACTANTS TO ASSESS POTASSIUM AVAILABILITY

Table 4. Inter correlations between different extractants

Extractants	Distilled water K	0.01M CaCl ₂ K	1N NH ₄ OAc K	Mehilich- 3 K	1 N HNO ₃ K
Distilled water K	1.000				
0.01M CaCl ₂ K	0.708**	1.000			
1N NH ₄ OAc K	0.480**	0.292	1.000		
Mehilich- 3 K	0.534**	0.329***	0.986**	1.000	
1 N HNO ₃ K	0.400*	0.331***	0.950**	0.987**	1.000

* Significant at 0.05 per cent level; **Significant at 0.01 per cent level

***Significant at 0.1 per cent level

Table 5. Correlation co-efficient (r) between different extractants and plant parameters

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.556**	0.507**	0.556**
0.01M CaCl ₂	0.466**	0.358*	0.391*
1N NH ₄ OAc	0.896**	0.887**	0.931**
Mehilich- 3	0.889**	0.885**	0.927**
1 N HNO ₃	0.897**	0.890**	0.933**

*Significant at 0.05 per cent level; **Significant at 0.01 per cent level

Table 6. Correlation co-efficient (r) between different extractants of K and plant parameters in rice-rice cropping system

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.841**	0.751**	0.798**
0.01M CaCl ₂	0.623**	0.533**	0.511**
1N NH ₄ OAc	0.923**	0.869**	0.939**
Mehilich- 3	0.920**	0.852**	0.926**
1 N HNO ₃	0.945**	0.902**	0.964**

**Significant at 0.01 per cent level

Table 7. Correlation co-efficient (r) between different extractants of K and plant parameters of maize-maize cropping system

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.541**	0.693**	0.642**
0.01M CaCl ₂	0.572**	0.74**	0.66**
1N NH ₄ OAc	0.912**	0.961**	0.971**
Mehilich- 3	0.854**	0.872**	0.879**
1 N HNO ₃	0.846**	0.917**	0.912**

**Significant at 0.01 per cent level

Table 8. Correlation co-efficient (r) between different extractants of K and plant parameters of rice-maize/rice mustard cropping system

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.936**	0.880**	0.914**
0.01M CaCl ₂	0.676**	0.858**	0.759**
1N NH ₄ OAc	0.969**	0.887**	0.944**
Mehilich- 3	0.986**	0.895**	0.965**
1 N HNO ₃	0.966**	0.942**	0.964**

**Significant at 0.01 per cent level

Table 9. Correlation co-efficient (r) between different extractants of K and plant parameters of fallow-bengal gram cropping system

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.140 ^{NS}	-0.01 ^{NS}	0.02 ^{NS}
0.01M CaCl ₂	0.04 ^{NS}	-0.13 ^{NS}	-0.07 ^{NS}
1N NH ₄ OAc	0.991**	0.941**	0.962**
Mehilich- 3	0.981**	0.907**	0.933**
1 N HNO ₃	0.946**	0.880**	0.925**

**Significant at 0.01 per cent level ; NS- Non- significant

Table 10. Correlation co-efficient (r) between different extractants of K and plant parameters in groundnut-groundnut cropping system

Plant parameters Extractants	Dry matter	K content	K uptake
Distilled water	0.510**	0.553**	0.512**
0.01M CaCl ₂	0.466**	0.419*	0.465**
1N NH ₄ OAc	0.985**	0.972**	0.987**
Mehilich- 3	0.973**	0.955**	0.975**
1 N HNO ₃	0.949**	0.927**	0.956**

**Significant at 0.01 per cent level ; * Significant at 0.05 per cent level

CONCLUSIONS

In the present study out of the all extractants studied in cropping systems and in the studied soils the extractability of potassium, were in the order of : 1 N HNO₃ > Mehilich-3 > N .N NH₄OAc > 0.01M CaCl₂ > Distilled water. Among all the extractants, significantly higher amounts of K were extracted by 1 N HNO₃ because in addition to exchangeable K, some of the non-exchangeable K is also brought into solution by the breakdown of primary and secondary clay minerals. Higher amount of potassium was extracted in maize-maize cropping system and lowest in groundnut-groundnut cropping system with all the extractants. Amount of potassium extracted was found to be higher in maize-maize cropping system than fallow Bengal gram cropping system even though fallow Bengal cropping system was grown in black soils, which might be due to lack of K fertilization which results in K depletion over period of time. The plant parameters of maize crop were higher in maize-maize cropping system and were lower in groundnut- groundnut cropping system. All these K extractants were positively correlated with each other, though these extractants removed different quantities of K which indicates that these methods can be used for assessment of availability of K in present investigated soils and also amount of potassium extracted were comparable. Among the 5 extractants tried, 1N HNO₃ showed

maximum positive and significant correlation with yield, content and uptake of potassium of maize crop followed by N NH₄OAc and Mehilich-3. The data revealed that maximum positive and significant correlation of plant parameters were found with NN NH₄OAc followed by 1 N HNO₃ in maize-maize cropping system, fallow-Bengal gram cropping system and groundnut-groundnut cropping system. Incase of rice-maize/mustard cropping system and rice-rice cropping system 1 N HNO₃ showed maximum positive and significant correlation followed by NN NH₄OAc. Hence, it can be concluded that 1 N HNO₃ can be used for estimation of available potassium along with 1N NH₄OAc, while giving fertilizer recommendation to increase potassium use efficiency.

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YIELD AND ECONOMICS OF MAIZE-CHICKPEA SEQUENCE AS INFLUENCED BY SOWING TIME AND NITROGEN LEVELS

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ABSTRACT

A field experiment was conducted on clay soils of Regional Agricultural Research Station, Guntur during *kharif* and *rabi* of 2013-14 and 2014-15 to find out the influence of sowing time and nitrogen levels on yield and economics of maize-chickpea sequence under rainfed agro-climatic condition of Krishna zone. Sowing time and nitrogen levels significantly influenced the economic yield of preceding maize and succeeding chickpea under of maize-chickpea sequence. From the sequence of preceding *kharif* maize followed by succeeding *rabi* chickpea, maximum net return of Rs.1,38,154 ha⁻¹ and Rs.1,38,936 ha⁻¹, respectively during the first and the second year was obtained with 1st FN of July sowing with 200 % of Recommended Dose of Nitrogen (RDN) to preceding *kharif* maize and 100 % RDN to succeeding *rabi* chickpea followed by 2nd FN July sowing with 150 % RDN to preceding *kharif* maize and 75 % RDN to succeeding *rabi* chickpea. While, the lower net return of Rs. 53,232 ha⁻¹ and Rs. 50,919 ha⁻¹ were obtained with 2nd FN July sowing with 100% of RDN to preceding *kharif* maize and 0% RDN to succeeding *rabi* chickpea. The benefit-cost ratio of maize-chickpea sequence ranged from 1.1 to 3.6 in first year and 1.2 to 3.9 in the second year with different treatments. The higher B:C ratio was obtained in 1st FN July sowing with 200 % RDN to preceding maize and 100% RDN to succeeding chickpea during both the years of experimentation.

INTRODUCTION

The predominant cropping system in rainfed areas of Krishna agro-climatic zone of Andhra Pradesh is with long duration crops such as cotton, chillies, etc under high input management. With increasing cost of cultivation and lower minimum support price, cotton and chilli farmers are under risk especially in rainfed areas. The crops are also being subjected to abiotic and biotic stresses frequently resulting in farmers falling into debt trap and consequent distress. The maize-chickpea sequence is found to be profitable than sole crop and also helps in soil fertility maintenance on long run in Krishna zone of Andhra Pradesh (Sharma and Behera, 2009). If this crop sequence is introduced to the Krishna agro-climatic zone of Andhra Pradesh, it will be beneficial in many ways. Both the crops together require comparatively shorter period to that of cotton and chilli and at the same time risk free with secured income to the farmer and sustainable to the soil health. Maize and chickpea crops has good market value and fetch higher prices than MSP announced

by GoI (MSP-Maize: Rs. 1310 q⁻¹ and Chickpea: Rs.3100 q⁻¹, respectively) (CACP, 2013). Among the maize based cropping systems, maize-chickpea is one which is recently introduced due to the changing scenario of natural resource base. Therefore, introduction of maize-chickpea with appropriate input management under rainfed conditions of Krishna zone may sustain the economy of the rainfed farmers. Hence, the present investigation was carried out to study the economic returns of the sequence.

MATERIAL AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Guntur (Latitude: 16°18', Longitude: 80°29', Altitude: 33 m). The climate is sub-tropical with mean annual rainfall of 950 mm. The soil of experimental field was clay loam in texture, neutral to slightly alkaline in reaction (pH 7.8 to 8.2) low in available N (204 kg ha⁻¹), high in P₂O₅ (96.5 kg ha⁻¹) and K₂O (886.5 kg ha⁻¹) and medium in organic carbon (0.51%), respectively. The experiment was conducted for two successive *kharif* and *rabi* seasons of 2013-14 and 2014-15 in Krishna agro-climatic zone of Andhra Pradesh. The

experiment consisting of three sowing windows as main plots treatments *viz.*, 2nd FN of June, 1st FN of July and 2nd FN of July, three nitrogen levels as sub-plot treatments *viz.*, 100 %, 150 % and 200 % RDN (RDN=200 kg N ha⁻¹) applied to preceding maize and four N levels as sub-sub plot treatments *viz.*, 0, 50 %, 75 % and 100 % RDN to succeeding chickpea (RDN=20 kg N ha⁻¹). All treatments were randomly allocated and replicated thrice in a split plot design for *kharif* crop and double split designs for *rabi* crop in both years of experimentation. Each main plot was divided into required size of three sub plots and each sub-plot again divided into four sub-sub plots of required size. Recommended dose of N for maize was applied in three splits ($\frac{1}{2}$ at sowing, $\frac{1}{4}$ at knee high stage and $\frac{1}{4}$ at tasselling stage) to preceding maize and entire dose of N was applied at the time of sowing to succeeding chickpea. A popular and non-lodging medium duration maize variety P-3396 and popular *desi* chickpea JG-11 were used in study. The data pertaining to soil, weather, yield attributes yield, gross returns and net returns was collected during crop growth period and analysed statistically by following the analysis of variance technique for split and double split design.

RESULTS AND DISCUSSION

Effect of sowing time and N levels on preceding maize

Kernel and stover yield of maize was affected significantly due to sowing time during both the years of study (Table 1). Significantly highest kernel and stover yield of maize was recorded with the crop sown on 2nd FN of June which was at par with 1st FN July sowing. It might be due to the better performance of early sown maize crop favoured by early sowing which intern utilize all the inputs and natural resources very efficiently. Adequate soil moisture that makes higher availability of nutrients in the soil, longer sunshine hours day⁻¹ resulting in more photosynthetic activity, efficient translocation to sink might have resulted higher kernel and stover yield in the early sown maize crop. Similar findings were also observed by Maryam *et al.* (2013) and Sreerekha *et al.* (2015).

The three nitrogen levels triad were found significant on kernel and stover yield of maize. Nitrogen applied at 200% RDN significantly recorded higher kernel and stover yield over 100% RDN but it was on a par with 150% RDN. The increased kernel and stover production with more nitrogen application might be due to the fact that nitrogen fertilization made the plants more efficient in photosynthetic activity, enhancing the carbohydrate metabolism and ultimately the increasing drymatter accumulation. Taller plants with more number of leaves with higher dose of nitrogen might have resulted in the higher drymatter accumulation resulted in higher kernel and stover yield (Table 1). The dwarf plants with little number of leaves at lower dose of nitrogen could be the reason for lower drymatter resulted in lower kernel and stover yield at lower nitrogen levels. These results are in conformity with findings of Wasnik *et al.* (2012), Ayub *et al.* (2013), Prathyusha and Hemalatha(2013), Maryam *et al.* (2013) and Sreerekha *et al.* (2015).

Effect of sowing time and N levels on succeeding chickpea

Grain and stover yield of succeeding chickpea was significantly influenced by sowing time and nitrogen levels applied to preceding maize and nitrogen levels applied to succeeding chickpea during both the years of study (Table 2). Significantly higher grain and stover yield of succeeding chickpea in both the years of study was recorded when its preceding maize was applied with 200% RDN. Application of higher dose of nitrogen (200 N kg ha⁻¹) to the previous crop leads to higher residual nitrogen to the succeeding crop. This might be the reason for the significant accumulation of drymatter in succeeding chickpea which in turn resulted in higher yield. These findings are in conformity with those of Nawale *et al.* (2009) and Thomas *et al.* (2010). Interaction effect between sowing time and nitrogen levels of preceding maize and nitrogen levels applied to succeeding chickpea was non significant on grain and stover yield either preceding maize nor succeeding chickpea during both the years of study (Table 1 and 2).

Table 1. Kernel yield of maize as influenced by sowing time and nitrogen levels

Treatments	drymatter accumulation (g m ⁻²) at harvest		Kernel yield (q ha ⁻¹)		Stover yield (t ha ⁻¹)	
	2013	2014	2013	2014	2013	2014
Main Plots: Sowing time (A)						
2 nd FN of June	2094.11	1894.11	95.52	94.87	12.38	12.29
1 st FN of July	1920.89	1720.89	93.48	92.83	11.14	10.99
2 nd FN of July	1637.67	1437.67	77.71	77.06	10.55	10.40
SEm ±	52.78	74.71	3.19	3.18	0.40	0.45
CD @ 5%	207.24	207.42	12.52	12.50	1.58	1.77
C V %	8.40	9.41	10.76	10.84	10.65	12.03
Sub-plots: N Levels (B)						
100 % RDN	1606.76	1406.78	81.40	80.75	9.48	9.38
150 % RDN	1936.11	1706.78	91.35	90.70	12.39	12.18
200 % RDN	2109.78	1909.78	93.96	93.31	12.20	12.11
SEm ±	68.06	96.23	2.61	2.61	0.37	0.39
CD @ 5 %	209.70	209.70	8.05	8.10	1.13	1.19
C V %	10.83	12.12	8.82	8.88	9.65	10.30
Interaction		NS	NS		NS	

NS - Non - Significant

Economics of maize-chickpea sequence

Gross and net returns and benefit-cost ratio were worked out for preceding maize, succeeding *rabi* chickpea separately and the system by taking into consideration of all the inputs used in *kharif* and *rabi* seasons, and the economic yield for both the seasons during the two years of the study are presented in (Table 3 and 4). From the sequence of preceding *kharif* maize followed by succeeding *rabi* chickpea, maximum net return of Rs.1,38,154 ha⁻¹ and Rs.1,38,936 ha⁻¹, respectively during the first and the second year was obtained with 1st FN of July sowing with 200% of RDN to preceding *kharif* maize and 100 % RDN to succeeding *rabi* chickpea followed by 2nd FN July sowing with 150% RDN to preceding *kharif* maize and 75% RDN to succeeding

rabi chickpea. While, the lower net return of Rs. 53,232 ha⁻¹ and Rs. 50, 919 ha⁻¹ were obtained with 2nd FN July sowing with 100% of RDN to preceding *kharif* maize and 0% RDN to succeeding *rabi* chickpea. The benefit- cost ratio of maize chickpea sequence ranged from 1.1 to 3.6 in first year and 1.2 to 3.9 in the second year with different treatments. The higher B:C ratio was obtained with 1st FN July sowing with 200 % RDN to preceding maize and 100% RDN to succeeding *rabi* chickpea. Higher yield benefiting higher return could be the reason for current results. These results are in accordance with the findings of Saini and Vinod Kumar (2001), Mosha and Raghavaiah (2003), Nawale *et al.* (2009), Lingaraju *et al.* (2010), Jnanasha *et al.* (2012) and Vidyavathi *et al.* (2011) and Mohankumar and Hiremath (2015).

Table 2. Grain yield of succeeding chickpea as influenced by sowing time and nitrogen levels

Treatments	drymatter accumulation (g m ⁻²) at harvest		Kernel yield (q ha ⁻¹)		Stover yield (t ha ⁻¹)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Main plots: Maize sowing window (A)						
2 nd FN of June	193.59	183.84	13.39	13.25	1.34	1.92
1 st FN of July	294.99	287.57	17.43	17.42	2.95	2.91
2 nd FN of July	272.18	265.02	15.50	15.39	2.72	2.65
SEm ±	11.25	8.79	0.09	0.11	0.04	0.07
CD @ 5 %	38.26	34.43	0.28	0.34	0.12	0.22
CV (%)	5.30	20.44	2.72	3.34	7.12	13.47
Sub plots: N applied to maize						
100% RDN	194.97	198.81	14.05	13.99	1.95	1.93
150% RDN	237.89	217.01	14.77	14.72	2.38	2.36
200% RDN	327.89	320.61	17.49	17.35	3.28	3.18
SEm ±	21.19	6.98	0.13	0.25	0.02	0.05
CD @ 5 %	64.28	21.49	0.38	0.76	0.07	0.15
CV (%)	3.73	17.00	4.80	9.70	4.89	12.04
sub-sub plots: N applied to chickpea						
0 % RDN	224.88	215.60	1224	12.20	2.22	2.20
50 % RDN	249.49	240.95	1462	14.48	2.49	2.45
75 % RDN	265.82	257.87	1637	16.29	2.67	2.65
100 % RDN	274.16	267.47	1852	18.45	2.76	2.67
SEm ±	25.10	13.72	0.16	0.27	0.02	0.06
CD @ 5 %	NS	45.04	0.49	0.82	0.07	0.19
CV (%)	9.49	6.95	5.90	9.81	4.18	19.98
Interaction	NS		NS		NS	

CONCLUSION

From the study it can be concluded that sowing maize during 1st FN of July with 200 % RDN followed by 100 % RDN to succeeding chickpea was found to be the best in terms of yield of maize-chickpea sequence as well as economic returns from the system.

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Table 3. Economics of maize- chickpea sequence during 2013-14

Treatments	2013-2014											
	Gross Return (Rs. ha ⁻¹)			Cost of Cultivation (Rs. ha ⁻¹)			Net Return (Rs. ha ⁻¹)			B:C Ratio		
	Maize	Chickpea	Sequence	Maize	Chickpea	Sequence	Maize	Chickpea	Sequence	Chickpea	Sequence	Maize
D ₁ N ₁ F ₁	131098	27017	158115	56674	22895	79569	74424	4122	78546	1.3	0.2	1.5
D ₁ N ₁ F ₂	131098	33478	164576	56674	22947	79621	74424	10531	84955	1.3	0.5	1.8
D ₁ N ₁ F ₃	131098	37855	168953	56674	22921	79595	74424	14934	89358	1.3	0.7	2.0
D ₁ N ₁ F ₄	131098	47126	178224	56674	23000	79674	74424	24126	98550	1.3	1.0	2.4
D ₁ N ₂ F ₁	143429	28585	172014	56674	22895	79569	86755	5690	92445	1.5	0.2	1.8
D ₁ N ₂ F ₂	143429	37340	180769	56674	22947	79621	86755	14393	101148	1.5	0.6	2.2
D ₁ N ₂ F ₃	143429	38004	181433	56674	22921	79595	86755	15083	101838	1.5	0.7	2.2
D ₁ N ₂ F ₄	143429	41976	185405	56674	23000	79674	86755	18976	105731	1.5	0.8	2.4
D ₁ N ₃ F ₁	145602	29502	175104	56674	22895	79569	88928	6607	95535	1.6	0.3	1.9
D ₁ N ₃ F ₂	145602	44422	190024	56674	22947	79621	88928	21475	110403	1.6	0.9	2.5
D ₁ N ₃ F ₃	145602	46482	192085	56674	22921	79595	88928	23561	112490	1.6	1.0	2.6
D ₁ N ₃ F ₄	145602	54089	199691	56674	23000	79674	88928	31089	120017	1.6	1.4	2.9
D ₂ N ₁ F ₁	126555	39014	165569	56674	22895	79569	69881	16119	86000	1.2	0.7	1.9
D ₂ N ₁ F ₂	126555	43521	170076	56674	22947	79621	69881	20574	90455	1.2	0.9	2.1
D ₂ N ₁ F ₃	126555	49701	176256	56674	22921	79595	69881	26780	96661	1.2	1.2	2.4
D ₂ N ₁ F ₄	126555	53307	179862	56674	23000	79674	69881	30307	100188	1.2	1.3	2.6
D ₂ N ₂ F ₁	141482	39787	181269	56674	22895	79569	84808	16892	101700	1.5	0.7	2.2
D ₂ N ₂ F ₂	141482	43920	185402	56674	22947	79621	84808	20973	105781	1.5	0.9	2.4
D ₂ N ₂ F ₃	141482	50989	192471	56674	22921	79595	84808	28068	112876	1.5	1.2	2.7
D ₂ N ₃ F ₁	148169	49315	197484	56674	22895	79569	91495	26420	117915	1.6	1.2	2.8
D ₂ N ₃ F ₂	148169	56268	204437	56674	22947	79621	91495	33321	124816	1.6	1.5	3.1

Contd...

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2013-2014												
Treatments	Gross Return (Rs. ha ⁻¹)			Cost of Cultivation (Rs. ha ⁻¹)			Net Return (Rs. ha ⁻¹)			B:C Ratio		
	Maize	Chickpea	Sequence	Maize	Chickpea	Sequence	Maize	Chickpea	Sequence	Maize	Chickpea	Sequence
D ₂ N ₃ F ₃	148169	58972	207141	56674	79595	91495	36051	127546	1.6	1.6	1.6	3.2
D ₂ N ₃ F ₄	148169	69659	217828	56674	79674	91495	46659	138154	1.6	2.0	2.0	3.6
D ₃ N ₁ F ₁	102542	30259	132801	56674	79569	45868	7364	53232	0.8	0.3	0.3	1.1
D ₃ N ₁ F ₂	102542	35924	138466	56674	79621	45868	12977	58845	0.8	0.6	0.6	1.4
D ₃ N ₁ F ₃	102542	42105	144647	56674	79595	45868	19184	65052	0.8	0.8	0.8	1.6
D ₃ N ₁ F ₄	102542	51246	153788	56674	79674	45868	28246	74114	0.8	1.2	1.2	2.0
D ₃ N ₂ F ₁	119318	36420	155738	56674	79569	62644	13525	76169	1.1	0.6	0.6	1.7
D ₃ N ₂ F ₂	119318	39662	158980	56674	79621	62644	16715	79359	1.1	0.7	0.7	1.8
D ₃ N ₂ F ₃	119318	50097	169415	56674	79595	62644	27176	89820	1.1	1.2	1.2	2.3
D ₃ N ₂ F ₄	119318	53688	173006	56674	79674	62644	30688	93332	1.1	1.3	1.3	2.4
D ₃ N ₃ F ₁	122012	41313	163325	56674	79569	65338	18418	83756	1.2	0.8	0.8	2.0
D ₃ N ₃ F ₂	122012	47126	169138	56674	79621	65338	24179	89517	1.2	1.1	1.1	2.2
D ₃ N ₃ F ₃	122012	52920	174932	56674	79595	65338	29999	95337	1.2	1.3	1.3	2.5
D ₃ N ₃ F ₄	122012	58586	180598	56674	79674	65338	35586	100924	1.2	1.5	1.5	2.7

Table 4. Economics of maize- chickpea sequence during 2014-15

Treatments	2014-2015											
	Gross Return (Rs. ha ⁻¹)			Cost of Cultivation (Rs. ha ⁻¹)			Net Return (Rs. ha ⁻¹)			B:C Ratio		
	Maize	Chickpea	Sequence	Maize	Maize	Chickpea	Sequence	Maize	Maize	Chickpea	Sequence	Maize
D ₁ N ₁ F ₁	123522	30407	153929	56674	22895	79569	66848	7512	74360	1.2	0.3	1.5
D ₁ N ₁ F ₂	123522	37733	161255	56674	22947	79621	66848	14786	81634	1.2	0.6	1.8
D ₁ N ₁ F ₃	123522	42715	166237	56674	22921	79595	66848	19794	86642	1.2	0.9	2.0
D ₁ N ₁ F ₄	123522	53264	176786	56674	23000	79674	66848	30264	97112	1.2	1.3	2.5
D ₁ N ₂ F ₁	135226	32165	167391	56674	22895	79569	78552	9270	87822	1.4	0.4	1.8
D ₁ N ₂ F ₂	135226	42128	177354	56674	22947	79621	78552	19181	97733	1.4	0.8	2.2
D ₁ N ₂ F ₃	135226	42861	178087	56674	22921	79595	78552	19940	98492	1.4	0.9	2.3
D ₁ N ₂ F ₄	135226	47403	182629	56674	23000	79674	78552	24403	102955	1.4	1.1	2.4
D ₁ N ₃ F ₁	137289	33191	170479	56674	22895	79569	80615	10296	90910	1.4	0.4	1.9
D ₁ N ₃ F ₂	137289	49087	186376	56674	22947	79621	80615	26140	106755	1.4	1.1	2.6
D ₁ N ₃ F ₃	137289	52531	189820	56674	22921	79595	80615	29610	110225	1.4	1.3	2.7
D ₁ N ₃ F ₄	137289	61176	198465	56674	23000	79674	80615	38176	118791	1.4	1.7	3.1
D ₂ N ₁ F ₁	119210	44033	163243	56674	22895	79569	62536	21138	83674	1.1	0.9	2.0
D ₂ N ₁ F ₂	119210	49161	168371	56674	22947	79621	62536	26214	88750	1.1	1.1	2.2
D ₂ N ₁ F ₃	119210	56194	175404	56674	22921	79595	62536	33273	95809	1.1	1.5	2.6
D ₂ N ₁ F ₄	119210	60297	179507	56674	23000	79674	62536	37297	99833	1.1	1.6	2.7
D ₂ N ₂ F ₁	133378	44912	178290	56674	22895	79569	76704	22017	98721	1.4	1.0	2.3
D ₂ N ₂ F ₂	133378	49601	182979	56674	22947	79621	76704	26654	103358	1.4	1.2	2.5
D ₂ N ₂ F ₃	133378	58760	192138	56674	22921	79595	76704	35839	112543	1.4	1.6	2.9
D ₂ N ₂ F ₄	133378	61837	195215	56674	23000	79674	76704	38837	115541	1.4	1.7	3.0
D ₂ N ₃ F ₁	139725	55755	195479	56674	22895	79569	83051	32860	115910	1.5	1.4	2.9

Contd...

Contd...

2014-2015												
Treatments	Gross Return (Rs. ha ⁻¹)			Cost of Cultivation (Rs. ha ⁻¹)			Net Return (Rs. ha ⁻¹)			B:C Ratio		
	Maize	Chickpea	Sequence	Maize	Maize	Chickpea	Sequence	Maize	Maize	Chickpea	Sequence	Maize
D ₂ N ₃ F ₂	139725	63667	203392	56674	22947	79621	83051	40720	123771	1.5	1.8	3.2
D ₂ N ₃ F ₃	139725	66744	206468	56674	22921	79595	83051	43823	126873	1.5	1.9	3.4
D ₂ N ₃ F ₄	139725	78905	218630	56674	23000	79674	83051	55905	138956	1.5	2.4	3.9
D ₃ N ₁ F ₁	96418	34070	130488	56674	22895	79569	39744	11175	50919	0.7	0.5	1.2
D ₃ N ₁ F ₂	96418	40517	136935	56674	22947	79621	39744	17570	57314	0.7	0.8	1.5
D ₃ N ₁ F ₃	96418	47550	143968	56674	22921	79595	39744	24629	64373	0.7	1.1	1.8
D ₃ N ₁ F ₄	96418	57953	154371	56674	23000	79674	39744	34953	74697	0.7	1.5	2.2
D ₃ N ₂ F ₁	112341	41081	153422	56674	22895	79569	55667	18186	73853	1.0	0.8	1.8
D ₃ N ₂ F ₂	112341	44766	157106	56674	22947	79621	55667	21819	77485	1.0	1.0	1.9
D ₃ N ₂ F ₃	112341	56634	168975	56674	22921	79595	55667	33713	89380	1.0	1.5	2.5
D ₃ N ₂ F ₄	112341	60737	173077	56674	23000	79674	55667	37737	93403	1.0	1.6	2.6
D ₃ N ₃ F ₁	114898	46671	161569	56674	22895	79569	58224	23776	82000	1.0	1.0	2.1
D ₃ N ₃ F ₂	114898	53264	168162	56674	22947	79621	58224	30317	88541	1.0	1.3	2.3
D ₃ N ₃ F ₃	114898	59857	174755	56674	22921	79595	58224	36936	95160	1.0	1.6	2.6
D ₃ N ₃ F ₄	114898	66304	181202	56674	23000	79674	58224	43304	101528	1.0	1.9	2.9

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EFFECT OF URBAN COMPOST APPLICATION TO SOIL ON GROUND WATER QUALITY

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ABSTRACT

A laboratory soil column experiment was conducted to study threat of heavy metals addition to ground water when urban compost was applied to soil as manure. The treatments imposed were : T₁ - Control, T₂ - Urban compost @ 20 t ha⁻¹, T₃ - Urban compost @ 40 t ha⁻¹, T₄ - T₂ + FYM @ 10 t ha⁻¹, T₅ - T₃ + FYM @ 10 t ha⁻¹, T₆ - T₂ + Humic acid @ 20 kg ha⁻¹, T₇ - T₃ + Humic acid @ 20 kg ha⁻¹, T₈ - T₂ + Biochar @ 5 t ha⁻¹ and T₉ - T₃ + Biochar @ 5 t ha⁻¹. The leachates collected during nine leaching events with three pore volumes of water were analysed for pH, EC, nitrates, COD and heavy metals. It was found that the treatments effect was significant on all the parameters studied. NO₃-N of leachates was more than 10 ppm in Urban compost + FYM treatments and when urban compost was added @ 40 t ha⁻¹. Iron, Zinc and Cr were not detected in the leachates of any treatment. Mn was recorded in treatments where biochar was applied. Heavy metals namely Pb, Ni, Co and Cd were high with high dose of urban compost more so in combinations of biochar, humic acid and FYM in descending order in case of Pb and Ni, and no specific trend in case of Co and Cd.

INTRODUCTION

In India, municipal solid waste generated during 2011-12 was 1,27,486 tonnes per day (TPD), out of which, 89,334 TPD (70%) of MSW was collected and 15,881 TPD (12.45%) was processed or treated. In Andhra Pradesh, *in toto* it was reported as 11, 500 TPD out of which 4200 TPD was from Hyderabad alone. There was an increase by about 2.7 times of that reported in 1999-2000 as per MoEF in 2012.

Greater Hyderabad Municipal Corporation proposed 'Integrated Municipal Solid Waste Management Project' in Jawaharnagar village, Shameerpet mandal, Rangareddy district for environmental clearance. As of now, in the East Zone, there are about 1,77,874 households and of them, 1,27,580 are covered by tricycles for collection of municipal solid waste. Similarly, in the West Zone, of the 2,23,611 households, about 1,51,064 are covered by tricycles. The proposed auto-tippers, after collecting garbage from door-to-door, will also go around the localities to clean up open dumps. The capital here generates 3,800 metric tons of garbage a day, of which it has been now established that

about 3,200 metric tons is transported to the dump yard. The urban compost is being added to agricultural land for both, waste disposal and to improve soil fertility. Hence, an attempt was made to study the impact of use of urban compost in agricultural soils on ground water quality.

MATERIAL AND METHODS

Leachate studies were conducted on soil columns to examine the transport of heavy metals beyond the depth of 45 cm in the Department of Environmental Science and Technology, College of Agriculture, Acharya N.G. Ranga Agricultural University (Presently PJTSAU) Rajendranagar in the year 2012. Soil passed through 2 mm sieve was packed in the column from bottom to top to a height of 45 cm maintaining the bulk density of 1.6 Mg m⁻³. A space of 5 cm was provided at the top (above the soil surface) for the application of water. Top 15 cm of the column was filled with 1/3rd of the calculated quantity of soil mixed with urban compost (UC) with/without amendments as per the treatment. The columns were mounted on plastic funnels provided with plastic jar for collection of leachates. The

treatments imposed were : T₁ - Control, T₂ - Urban compost @ 20 t ha⁻¹, T₃ - Urban compost @ 40 t ha⁻¹, T₄ - T₂ + FYM @ 10 t ha⁻¹, T₅ - T₃ + FYM @ 10 t ha⁻¹, T₆ - T₂ + Humic acid @ 20 kg ha⁻¹, T₇ - T₃ + Humic acid @ 20 kg ha⁻¹, T₈ - T₂ + Biochar @ 5 t ha⁻¹ and T₉ - T₃ + Biochar @ 5 t ha⁻¹.

Leachate study

The leaching study was carried out based on pore volume. A pore volume is the volume of water required to replace water in a certain volume of saturated porous media. Accordingly, one pore volume of each column prepared was equal to 1480 ml of water. For every leaching event 493.3 ml water was used and nine leaching events were done (three pore volumes).

The columns were allowed to saturate for 24 hours, then the first leachate was collected by adding 493.3 ml of water *i.e.*, 1/3 pore volume. Similarly, after every 24 hours, leachates were collected upto ninth leaching event. Accumulated leachate was analyzed for pH, EC, nitrates, micronutrients (Fe, Mn, Zn and Cu), heavy metals (Pb, Ni, Co, Cd and Cr) and chemical oxygen demand (COD) following standard procedures of water analysis (Tandon, 1999). The water used for leachate studies was with pH of 7.43, EC of 0.25 dS m⁻¹, COD of 111.65 and NO₃-N of 0.99 mg L⁻¹. The recorded values of heavy metals were 0.013, 0.018, 0.019, 0.138 and 0.309 ppm for Cu, Cd, Ni, Pb and Co, respectively. Iron, Mn, Zn and Cr were not detected.

The data obtained from the laboratory soil column experiment was analysed in Completely Randomized Design with factorial and the significance was tested by 'F' test.

RESULTS AND DISCUSSION

In order to know the extent of leaching of heavy metals when urban compost was applied alone or in combination with farm yard manure/ humic acid/ biochar to soil, accumulated leachates collected during nine leaching events were analysed (Table 1) and discussed hereunder.

Reaction (pH)

The pH of leachate from urban compost treatment application was on par with Control (soil alone). There was an increase in pH with the addition of FYM and Biochar (BC) over the respective base dosage of urban compost; however, no trend was noticed on humic acid (HA) addition along with urban compost (Table 1). Application of Urban compost @ 20 t ha⁻¹ did not affect the pH of the leachate but a higher level of 40 t ha⁻¹ increased the pH of leachate. Addition of FYM along with Urban compost (T₄ and T₅) increased pH of leachates compared to T₂ (UC @ 20 t ha⁻¹) and T₃ (UC @ 40 t ha⁻¹). FYM leads to acidification of the soil by the way of leaching of exchangeable bases (Ca²⁺, Mg²⁺, Na⁺ and K⁺) into soil solution and subsequently resulting in their leaching. Rama Krishna (2008) also reported the same. However, the pH was within the range suitable for irrigation use (Tandon, 1999). In the treatments T₈ (UC @ 20 t ha⁻¹ + Biochar @ 5 t ha⁻¹) and T₉ (UC @ 40 t ha⁻¹ + Biochar 5 t ha⁻¹) the mean pH values (7.48, 7.54, respectively) were higher compared to T₁ (control), which could be because of alkalinity of the biochar.

Electrical Conductivity

Electrical conductivity, an index of salt loading, was significantly influenced by the addition of organic sources. The mean value of EC of leachates significantly increased in all the treatments compared to the control (Table 1). Among all the treatments, the leachate of the treatment T₅ (UC @ 40 t ha⁻¹ + FYM @ 10 t ha⁻¹) recorded the highest value and lowest was recorded in T₁ (control). Increase in EC values was very well correlated with the application of urban compost along with farm yard manure, humic acid and biochar in the form of different treatments. Significantly higher alkalinity of leachate from urban compost and FYM treated soil could be due to the acid leaching of base components in to the leachate. Higher EC of leachate from biochar applied soil could be due to the reason that the salts added to soil through organic sources might get dissolved in water and leached down into leachates. However, the percent increase in EC was highest

Table 1. Effect of urban compost application to soil on leachates (mean over 3 columns)

Treatment	pH	EC dS m ⁻¹	COD	NO ₃ -N mg L ⁻¹	Mn	Cu	Ni	Pb	Co	Cd
T ₁ Soil alone	7.43	2.51	211.65	1.00	BDL*	0.013	0.019	0.138	0.309	0.018
T ₂ UC @ 20 t ha ⁻¹	7.43	2.63	213.28	5.39	BDL	0.017	0.020	0.148	0.317	0.019
T ₃ UC @ 40 t ha ⁻¹	7.45	2.70	380.63	10.09	BDL	0.016	0.047	0.172	0.242	0.014
T ₄ UC @ 20 t ha ⁻¹ + FYM @ 10 t ha ⁻¹	7.61	2.76	272.34	13.09	BDL	0.017	0.064	0.171	0.323	0.021
T ₅ UC @ 40 t ha ⁻¹ + FYM @ 10 t ha ⁻¹	7.60	3.64	315.00	14.94	BDL	0.019	0.108	0.186	0.246	0.016
T ₆ UC @ 20 t ha ⁻¹ + HA @ 20 Kg ha ⁻¹	7.68	2.99	200.16	3.81	BDL	0.022	0.166	0.261	0.317	0.014
T ₇ UC @ 40 t ha ⁻¹ + HA @ 20 Kg ha ⁻¹	7.36	2.91	232.72	4.48	BDL	0.020	0.210	0.343	0.278	0.015
T ₈ UC @ 20 t ha ⁻¹ + BC @ 5 t ha ⁻¹	7.48	2.63	216.57	5.09	1.630	0.022	0.192	0.334	0.356	0.016
T ₉ UC @ 40 t ha ⁻¹ + BC @ 5 t ha ⁻¹	7.54	2.80	239.54	2.90	3.590	0.023	0.210	0.360	0.321	0.020
CD (5%)	0.020	0.044	18.582	1.575	0.015	0.004	0.018	0.011	0.018	0.004
SEM ±	0.007	0.015	6.206	0.526	0.005	0.001	0.006	0.004	0.006	0.001

UC – Urban Compost; HA- Humic Acid; BC- Biochar; *BDL- Below Detectable Limit and was taken as zero for statistical analysis;
 COD –Chemical Oxygen Demand

with FYM combination followed by humic acid and biochar. Ananda *et al.* (2006) also reported an increase in electrical conductivity due to the application of organic sources.

Chemical Oxygen Demand

COD was significantly influenced by different treatments of urban compost with FYM, humic acid and biochar. The increase in COD on application of urban compost was non-significant when applied @ 20 t ha⁻¹ and was significant when applied @ 40 t ha⁻¹ compared to Control. Shaheda Niloufer *et al.* (2013) also observed high COD values in the ground water because of the leachate percolation from MSW landfill. No specific trend was observed with the addition of FYM/biochar component to urban compost. With the conjunctive use of humic acid, COD values recorded were low compared to application of UC alone, which might be due to the interaction of both urban compost and humic acid.

Nitrates (NO₃-N)

Nitrates content was high when urban compost was applied to soil compared to T₁ (control) was high, but not significant when applied @ 20 t ha⁻¹. NO₃-N of leachates was more than 10 ppm in Urban compost + FYM treatments and when urban compost was added @ 40 t ha⁻¹. In the treatments of T₄ (UC @ 20 t ha⁻¹+ FYM @ 10 t ha⁻¹) and T₅ (UC @ 40 t ha⁻¹ + FYM @ 10 t ha⁻¹) the mean NO₃-N values (13.09, 14.94 mg l⁻¹) were higher compared to T₂. However, addition of humic acid (T₆ and T₇) and biochar (T₈ and T₉) along with urban compost decreased nitrates content in leachate which could be due to their interaction with urban compost. The leachate quality with respect to NO₃-N was 'moderate' (5 to 30 mg l⁻¹) as per Tandon (1999). Ground water contamination with nitrates leached from MSW landfill sites in Chennai was observed by Raman and Narayanan (2008).

Heavy metals

Data on heavy metals content as given in Table 1 indicates the significant effect of treatments.

Iron, Zinc and Chromium

Iron, zinc and chromium were not detected in the leachates of any treatment and in the water used for the leachate study.

Manganese

Mn was not detected in leachates from the treatments, T₁ to T₇ and in the water used for the study. But in treatments where biochar was added @ 5 t ha⁻¹ (T₈ and T₉) Mn was recorded as 1.630 and 3.590 ppm, respectively indicating that application of biochar increased the availability of Mn. Manganese content in leachates was higher than irrigation water standards *i.e.*, 0.2 ppm as per Tandon (1999) and ground water WHO standards which should be < 0.4 ppm (Musa *et al.*, 2013).

Copper

Urban compost application, T₂ (20 t ha⁻¹) and T₃ (40 t ha⁻¹), recorded significantly higher values of Cu compared to control (T₁), however, they were statistically on par. This could be because of higher copper content in urban compost. The values were higher with addition of FYM, humic acid and biochar in ascending order compared to T₂ and T₃.

Nickel

Ni content in leachates was found increased with successive addition of urban compost (T₂ and T₃) compared to T₁ (control). Similarly, addition of FYM, humic acid and biochar recorded higher Ni values of leachates, compared to respective doses of urban compost, T₂ (UC @ 20 t ha⁻¹) and T₃ (UC @ 40 t ha⁻¹). The leachate from soil column where urban compost was applied @ 40t ha⁻¹ along with humic acid or biochar were higher than the permissible limits of irrigation water (<0.2ppm as per Tandon, 1999) and ground water (<0.02 ppm as per WHO standards as reported by Musa *et al.*, in 2013). The finding of possibility of contamination of ground water by leaching of Ni was in accordance with the reports of Seyede (2013).

Lead

Application of urban compost @ 20 and 40 t ha⁻¹ resulted in significantly higher values of Pb in leachates over control. Similarly, inclusion of FYM @ 10 t ha⁻¹, humic acid @ 20 kg ha⁻¹ and biochar @ 5 t ha⁻¹ to urban compost also resulted in significantly higher Pb content in leachates compared to

respective urban compost doses *i.e.*, T₂ UC @ 20 t ha⁻¹ and T₃ UC @ 40 t ha⁻¹. Lead limits were in compliance with standards of irrigation water *i.e.*, < 5 ppm as per Tandon (1999) and WHO ground water standard of max.0.4 ppm (Musa *et al.*, 2013). The leaching of lead from MSW dump sites into the ground water was recorded by Effiong and Percy (2013).

Cobalt

Cobalt content varied significantly among the treatments. In general, it was high with urban compost application @ 20 t ha⁻¹ compared to control, but while adding more urban compost to 40 t ha⁻¹ recorded low Co value (0.242 ppm). The same trend was noticed in treatment combinations of UC @ 40 t ha⁻¹ + FYM/humic acid/biochar compared to their respective combinations with UC @ 20 t ha⁻¹.

Cadmium

In general, Cd values in leachates were higher than the permissible limit of max.0.003 ppm in ground water as per World Health Organization (Musa *et al.*, 2013). Urban compost application @ 20 t ha⁻¹ to soil resulted in slightly higher Cd content in leachate compared to control. The leaching of Cd from MSW dump sites into the ground water was recorded by Effiong and Percy (2013). It was observed that Biochar addition @ 5 t ha⁻¹ could decrease the Cd content in leachate when urban compost was applied in lower dose @ 20 ha⁻¹ but was not effective with respect to Cd in leachate at higher dose of 40 t ha⁻¹. Whereas humic acid @ 20 kg ha⁻¹ was effective in reducing Cd content of leachates at both doses of urban compost application.

CONCLUSION

Urban compost application to soil to 40 t ha⁻¹ (with similar quality as that used in the study) could be applied to soil with caution as there is a possibility of addition of lead and nickel to ground water on continuous use over a period of time.

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WEED MANAGEMENT WITH PRE AND POST EMERGENCE HERBICIDES IN MAIZE

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ABSTRACT

A field experiment was conducted at the Regional Agricultural Research Station, Guntur, Andhra Pradesh during *rabi* season of 2013 and 2014 to evaluate the efficacy of pre emergence herbicides atrazine, pendimethalin and post-emergence herbicides tembotrione and topramezone combinations against weed flora in maize. The experimental field was highly infested with *Cynodon dactylon*, *Dactyloctenium aegyptium* and *Digitaria arvensis* among grasses, *Cyperus rotundus* among sedges, *Trianthema portulacastrum*, *Cleome viscosa*, *Euphorbia hirta* and *Phyllanthus niruri* among broad leaf weeds. Lowest weed density and weed dry weight was recorded in application of atrazine@ 1.25 kg a.i ha⁻¹ as pre-emergence followed by topramezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₆), pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence followed by topramezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₈), atrazine@ 1.25 kg a.i ha⁻¹ as pre-emergence followed by tembotrione@110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₇) and pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence followed by tembotrione@110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₉) where sequential application of herbicides at all stages of crop growth.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important crops among the cereals in the world agricultural economy both as food and fodder crop. In India, during 2014-15 maize was cultivated in 9.2 million ha with 24.17 million tonnes production, and with a productivity of 2.56 t ha⁻¹. In Andhra Pradesh, the crop is cultivated in an area of 0.99 mha with 4.23 million tonnes production and 4257 kg ha⁻¹ (AICRP on Maize, 2016). Among the several factors, most dominant factor responsible for the lower yields of maize are weeds, which competes with crop for nutrients, water, sunlight and space. Wide spacing, intensive use of inputs and initial slow growth of maize are some of the factors responsible for increased weed growth. With the discovery of synthetic herbicides in the early 1930s, there was a shift in control methods towards high input and target-oriented ones (Singh *et al.*, 2003). Nowadays labour component in agriculture is becoming scarce. Use of herbicides to manage weeds forms an excellent alternative to manual weeding. In India, till date only pre-emergence application of atrazine /pendimethalin

has been widely recommended for the control of weeds in maize. There is a need of post-emergence herbicide usage for management of weeds which occur at 15-25 days of crop and offer severe competition for growth resources, thereby lowering the productivity of maize. Hence, it is proposed to test the new post emergence herbicides without residual effect in maize has greater field applicability. In most farming systems, competition for N is the most important factor than that of for all other nutrients and it is well known that large fraction of the millions of tonnes of nutrients added to soils every year are not taken up by crop plants, as up to 50% of added nitrogen and 0.4 to 90% of added phosphorus going waste from crop fields (Simpson *et al.*, 2011). This situation can be alleviated by employing microbial inoculants, which are beneficial to soil and rhizobacteria capable of promoting plant growth while reducing fertilizer inputs up to 50% without any yield loss compared to fully fertilized controls (Hayat *et al.*, 2010). Keeping all these in view, the present investigation was proposed to evaluate different pre and post emergence herbicides against mixed weed

complex in maize during *rabi* season of 2013 and 2014.

MATERIAL AND METHODS

A field experiment was conducted at the Regional Agricultural Research Station, Guntur, during *rabi* season of 2013 and 2014 in split plot design with nine weed management treatments as main plots and three fertilizer treatments as sub plots and all the treatments replicated thrice. Details are given below:

Main plots

T₁- Weedy check, T₂- Atrazine@ 1.25 kg a.i ha⁻¹ as pre-emergence, T₃- Pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence, T₄- Topramezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence, T₅- Tembotrione@110 g a.i ha⁻¹ at 20 DAS as post-emergence, T₆- Atrazine@ 1.25 kg a.i ha⁻¹ as pre-emergence, fb Topramezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence, T₇- Atrazine@ 1.25 kg a.i ha⁻¹ as pre-emergence fb Tembotrione@110 g a.i ha⁻¹ at 20 DAS as post-emergence, T₈- Pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence fb Topramezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence, T₉- Pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence fb Tembotrione@110 g a.i ha⁻¹ at 20 DAS as post-emergence.

Sub-Plots

F₁- 50% RDF+ bio consortium (Azospirillum (5 kg ha⁻¹) + phosphate solubilizing bacteria (5 kg ha⁻¹) + potash solubilizing bacteria (5 kg ha⁻¹) + vasicular arbuscular mycorrhiza (12.5 kg ha⁻¹) + vermicompost (500 kg ha⁻¹)

F₂- 75% RDF+ bioconsortium (Azospirillum (5 kg ha⁻¹) + phosphate solubilizing bacteria (5 kg ha⁻¹) + potash solubilizing bacteria (5 kg ha⁻¹) + vasicular arbuscular mycorrhiza (12.5 kg ha⁻¹) + vermicompost (500 kg ha⁻¹); F₃- 100% RDF

Maize crop variety pioneer 30 V 92 is used for the study in both the years in main plots of size 9.6 m x 4.8 m and sub plots 4.8 m x 2.9 m. Herbicides were sprayed with Knapsack sprayer fitted with flat fan nozzle. The different cultural practices recommended for maize crop were adopted during the crop growth period. Weed sampling was done randomly by placing a 0.5 m x 0.5 m quadrat at two different locations in the experimental unit to assess the weed flora at 30, 90 DAS and at harvesting stages. Dry weight of total weed species was recorded after drying and expressed in g m⁻².

The original data on weed densities and weed weights were subjected to square root transformation ($Vx+0.5$) before statistical analysis. The original values were given in parentheses. Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences (CD) were calculated for those parameters, which turned significant ($P \leq 0.05$) to compare the effects of different treatments.

RESULTS AND DISCUSSION

Weed flora of the experimental plot during the course of investigation were collected, identified and presented in Table 1. There were fifteen species of weeds belonging to eleven different families. The weed flora consisted of four different grasses belonging to poaceae family with *Cynodon dactylon* was predominant weed in the experimental field. In sedges only *Cyperus rotundus* was recorded where as incase of dicots, ten weed species belonging to nine different families were observed. Of which, *Trianthema portulacastrum*, *Cleome viscosa*, *Euphorbia hirta* and *Phyllanthus niruri* were the major weeds observed. Vanaja (2007) and Srividya *et al.* (2011) have reported the similar weed flora in their experiments conducted in black soils of Krishna Zone of Andhra Pradesh.

All the weed management practices influenced the weed density in maize in both the

years of study at all the stages of crop growth when compared to weedy check. At 30 DAS (Table 2) all the weed management practices were on par with each other except atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence (T₂) and pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence (T₃). The lowest total weed density (2.9 and 2.9 number m⁻²) was recorded in atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence followed by tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₆) and was on par with T8 atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence followed by tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₇) and pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence followed by tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₉) with which it was at par., and significantly superior to rest of the treatments. The reduced weed density in these treatments (T₆ to T₉) may be due to the fact that the weeds were controlled by sequential application at two stages *i.e.*, pre emergence and post emergence at 20 DAS. Similar line of observations were reported by Patel *et al.* (2006) and Malviya and Singh (2007). Significantly lower weed dry density was recorded in topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₄) and tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₅) treatments because of the post-emergence spray at 20 DAS which effectively controlled the weeds and resulted in low weed density at 30 DAS. At 90 DAS (Table 3) and at harvest (Table 4) almost similar trend was noticed in both the years of study in which all the sequential applications were on par with each other. With regard to nutrient management treatments there is no significant difference among the treatments on weed density at all stages of crop growth. All the three nutrient practices (F1, F2 and F3) are on-par with each other at 30 DAS, 90 DAS and maturity during both the years of study.

Critical review of the data indicates that sequential application of pre emergence herbicides followed by post emergence application of topamezone or tembotrione reduced the weed

density considerably and resulted in lowest weed density among these treatments. The better performance of sequential application might be due to the effective control of weeds at critical stages. The present findings are in conformity with the findings of Sreenivas and Satyanarayana (1994), Sinha *et al.* (2003) and Sonawane *et al.* (2014). Nutrient management practices did not show any impact on weed density at any stage of the crop and there was no interaction effect among the treatments in both the years.

Total weed dry matter

Total weed dry matter was recorded at 30, 90 DAS and at maturity during both the years of investigation. At 30 DAS (Table 5) all herbicidal treatments were significantly superior over weedy check in both the years of studies. Significantly, the lowest weeds dry weight (2.9 and 3.3 g. m⁻²) of total weeds was recorded in atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence followed by topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₆) as compared to all other treatments except, treatments topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₄), tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₅), pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence followed by topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₈), atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence followed by tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₇) and pendimethalin @ 0.75 kg a.i ha⁻¹ as pre-emergence followed by tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₉) with which it was at par. This could be attributed to reduced weed competition in the initial stage and control of late emerged weeds by sequential spray which led to lower weeds density and lower weed dry matter. Similar findings were reported by Patel *et al.* (2006) and Ahmed and susheela (2012). Significantly lower weed dry weight was recorded in topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₄) and tembotrione @ 110 g a.i ha⁻¹ at 20 DAS as post-emergence (T₅)

Table 1. Weed flora of the experimental field

S.No	Botanical Name	Common Name	Family
I Grasses			
1	<i>Cynodon dactylon</i>	Bermuda grass	Poaceae
2	<i>Dactyloctenium aegyptium</i>	Crow foot grass	Poaceae
3	<i>Digitaria sanguinalis</i>	Large crab grass	Poaceae
4	<i>Panicum repens</i>	Torpedo grass	Poaceae
II Sedges			
1	<i>Cyperus rotundus</i>	Purple nutsedge	Cyperaceae
III Broad leaf weeds			
1	<i>Borreria hispida</i>	Button weed	Rubiaceae
2	<i>Cleome viscosa</i>	Wild mustard	Capparidaceae
3	<i>Commelina benghalensis</i>	Day flower	Commelinaceae
4	<i>Euphorbia hirta</i>	Garden spurge	Euphorbiaceae
5	<i>Phyllanthus niruri</i>	Stone breaker	Euphorbiaceae
6	<i>Sida acuta</i>	Broom weed	Malvaceae
7	<i>Trianthema portulacastrum</i>	Horse pursulane	Aizoaceae
8	<i>Tribulus terrestris</i>	Puncture vine	Zygophyllaceae
9	<i>Trichodesma indicum</i>	Indian borage	Boraginaceae
10	<i>Tridax procumbense</i>	Mexican Daisy	Compositae

treatments because of the post-emergence spray at 20 DAS which effectively controlled the weeds and resulted in low weed dry weight at 30 DAS. The highest weed dry weight (12.7 and 13.4 gm⁻², respectively) was recorded in weedy check during both the years of study. Similar trend was continued at 90 DAS (Table 6) and at harvest (Table 7) also during both the years of study.

All the nutrient treatments (F1, F2 and F3) are on-par with each other at 30 DAS, 90 DAS and maturity during both the years of study. There

was no significance among the nutrient management treatments in sub plots during the two years of study and there was no interaction effect among the treatments. An appraisal of the data indicated that the weed dry matter showed gradual increase up to harvest even though the weed density declined after 60 DAS. This may be because of accumulation of more dry matter in weeds which was due to lower competition among weeds for resources. It also indicated that nutrient levels did not influence the weed dry matter at any stage of the crop growth.

Table 2. Density of total weeds (No. m⁻²) at 30 DAS in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14				Mean	2014-15			
		Nutrient Levels (Sub)					Nutrient Levels (Sub)			
		F1	F2	F3	Mean		F1	F2	F3	Mean
T ₁	Weedy check	9.2 (86.3)	8.8 (78.3)	9.0 (82.0)	9.0 (82.2)	9.3 (87.0)	8.9 (80.3)	9.1 (82.0)	9.1 (83.1)	
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	4.9 (24.3)	4.8 (24.0)	5.0 (25.0)	4.9 (24.4)	4.8 (23.0)	4.8 (23.0)	4.5 (21.7)	4.8 (22.6)	
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	5.1 (27.3)	5.4 (30.7)	5.0 (26.0)	5.2 (28.0)	5.7 (32.3)	5.5 (31.0)	5.1 (27.3)	5.4 (30.2)	
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.9 (14.7)	3.9 (14.7)	3.7 (13.3)	3.8 (14.2)	4.1 (16.7)	4.0 (15.3)	3.7 (13.7)	3.9 (15.2)	
T ₅	Tembotrione @ 110 gai ha ⁻¹ at 20 DAS as post-emergence	4.1 (16.0)	3.9 (14.7)	4.0 (15.3)	4.0 (15.3)	4.2 (17.3)	4.1 (16.3)	3.9 (14.7)	4.1 (16.1)	
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	2.9 (8.0)	2.9 (7.7)	3.0 (8.3)	2.9 (8.0)	2.8 (7.7)	2.8 (7.7)	3.0 (8.7)	2.9 (8.0)	
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 gai ha ⁻¹ at 20 DAS as post-emergence	3.3 (10.7)	3.5 (11.7)	3.3 (10.3)	3.4 (10.9)	3.4 (11.0)	3.3 (10.7)	3.4 (11.3)	3.4 (11.0)	
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.0 (9.0)	3.0 (8.7)	3.2 (9.7)	3.1 (9.1)	3.1 (9.3)	3.0 (8.3)	3.4 (11.0)	3.1 (9.6)	
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 gai ha ⁻¹ at 20 DAS as post-emergence	3.5 (12.0)	3.4 (11.3)	3.4 (11.3)	3.5 (11.6)	3.7 (13.0)	3.1 (9.3)	3.7 (13.3)	3.5 (11.9)	
	Mean	4.4 (23.1)	4.4 (22.4)	4.4 (22.4)		4.6 (24.1)	4.4 (22.4)	4.4 (22.6)		
	Weed management practices (Main)	0.5	0.6	32.7		0.4	1.2	27.8		
	Nutrient levels (Sub)	0.1	NS	11.7		0.1	NS	10.8		
	Weed management practices x Nutrient levels	0.8	NS			0.7	NS			

Note: Data transformed to $\sqrt{x+0.5}$ transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

Table 3. Density of Total weeds (No. m⁻²) at 90 DAS in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14			Mean	2014-15			Mean
		Nutrient Levels (Sub)				Nutrient Levels (Sub)			
		F ₁	F ₂	F ₃		F ₁	F ₂	F ₃	
T ₁	Weedy check	9.3 (87.0)	9.1 (82.7)	9.1 (84.7)	9.2 (84.8)	9.0 (80.3)	9.0 (81.7)	9.0 (82.0)	
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	5.5 (30.0)	5.3 (27.3)	5.4 (30.0)	5.4 (29.1)	5.4 (30.3)	5.6 (31.7)	5.6 (31.2)	
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	6.0 (36.0)	6.0 (36.0)	6.1 (37.3)	6.0 (36.4)	6.0 (37.0)	5.8 (34.3)	6.0 (36.4)	
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	5.3 (28.3)	4.9 (24.0)	5.2 (26.3)	5.1 (26.2)	5.6 (31.0)	5.4 (28.3)	5.5 (29.7)	
T ₅	Tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	5.0 (24.7)	5.3 (28.7)	5.2 (27.0)	5.2 (26.8)	5.6 (30.7)	5.5 (29.7)	5.5 (30.3)	
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.7 (13.3)	3.5 (12.0)	3.6 (12.7)	3.6 (12.7)	3.8 (14.0)	3.8 (14.0)	3.8 (13.8)	
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 gai ha ⁻¹ at 20 DAS as post-emergence	3.9 (14.7)	4.0 (15.3)	3.8 (14.0)	3.9 (14.7)	3.9 (15.0)	4.1 (16.3)	4.0 (15.8)	
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topamezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.7 (13.3)	3.6 (12.7)	3.8 (14.7)	3.7 (13.6)	3.9 (15.3)	4.0 (15.3)	3.9 (15.2)	
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 gai ha ⁻¹ at 20 DAS as post-emergence	4.0 (15.3)	4.1 (16.0)	3.8 (14.7)	3.9 (15.3)	3.9 (14.7)	4.1 (16.3)	4.0 (16.2)	
	Mean	5.2 (29.2)	5.1 (28.3)	5.1 (29.0)		5.2 (29.7)	5.2 (29.7)		
	Weed management practices (Main)	0.3	1.0	20.3		1.1	20.4		
	Nutrient levels (Sub)	0.1	NS	13.1		NS	9.2		
	Weed management practices x Nutrient levels	0.6	NS			NS			

Note: Data transformed to 'x+0.5 transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

Table 4. Density of total weeds (No. m⁻²) at harvest in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14			Mean	2014-15			Mean
		Nutrient Levels (Sub)				Nutrient Levels (Sub)			
		F ₁	F ₂	F ₃		F ₁	F ₂	F ₃	
		50% RDF+MI	75% RDF+MI	100% RDF		50% RDF+MI	75% RDF+MI	100% RDF	
T ₁	Weedy check	8.4 (70.7)	8.2 (66.3)	8.3 (68.0)	8.3 (68.3)	8.3 (69.7)	8.2 (67.3)	8.0 (65.0)	8.2 (67.3)
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	4.6 (20.7)	4.3 (18.3)	4.7 (21.3)	4.5 (20.1)	4.9 (23.3)	4.7 (21.3)	4.8 (23.7)	4.8 (22.8)
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	5.0 (25.0)	5.2 (27.3)	5.0 (25.0)	5.1 (25.8)	5.1 (26.3)	5.2 (26.7)	5.1 (26.0)	5.1 (26.3)
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	4.6 (20.3)	4.5 (18.0)	4.4 (19.3)	4.5 (19.2)	4.5 (20.3)	4.5 (22.3)	4.5 (21.3)	4.5 (21.3)
T ₅	Tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	4.2 (17.3)	4.5 (20.0)	4.7 (22.0)	4.5 (19.8)	4.6 (20.7)	4.6 (20.7)	4.6 (21.3)	4.6 (20.9)
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	2.7 (7.3)	2.6 (7.0)	2.5 (7.0)	2.6 (7.1)	2.9 (8.3)	2.9 (8.3)	2.8 (8.0)	2.9 (8.2)
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	2.9 (8.3)	3.1 (10.0)	2.9 (8.0)	3.0 (8.8)	3.1 (9.3)	3.0 (8.7)	3.2 (10.0)	3.1 (9.3)
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	2.8 (7.3)	2.9 (8.0)	2.8 (8.3)	2.8 (7.9)	3.0 (8.7)	3.3 (10.3)	2.8 (8.0)	3.0 (9.0)
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	3.1 (9.3)	3.1 (9.0)	2.9 (9.0)	3.0 (9.1)	3.2 (9.7)	3.0 (9.0)	3.3 (10.7)	3.2 (9.8)
	Mean	4.2 (20.7)	4.3 (20.4)	4.2 (20.9)		4.4 (21.8)	4.4 (21.6)	4.4 (21.6)	
	Weed management practices (Main)	0.3	0.8	18.6		0.3	0.9	20.3	
	Nutrient levels (Sub)	0.1	NS	17.7		0.2	NS	18.5	
	Weed management practices x Nutrient levels	0.5	NS			0.5	NS		

Note: Data transformed to 'x+0.5 transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

Table 5. Dry weight of total weeds at 30 DAS (g m⁻²) in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14			2014-15			Mean	Mean
		Nutrient Levels (Sub)			Nutrient Levels (Sub)				
		F ₁	F ₂	F ₃	F ₁	F ₂	F ₃		
T ₁	Weedy check	13.1 (171.5)	12.5 (156.4)	12.7 (159.7)	13.6 (184.8)	13.1 (173.1)	13.6 (184.4)	12.8 (162.5)	13.4 (180.8)
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	5.3 (27.8)	5.5 (31.6)	5.2 (26.8)	5.8 (33.8)	5.9 (34.2)	5.7 (32.0)	5.3 (28.7)	5.8 (33.3)
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	5.7 (32.5)	5.4 (28.6)	5.4 (28.3)	6.6 (43.2)	5.7 (31.8)	5.7 (32.5)	5.5 (29.8)	6.0 (35.8)
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.3 (10.7)	3.8 (14.3)	3.5 (11.8)	3.9 (14.9)	3.9 (16.1)	3.9 (14.9)	3.6 (12.2)	3.9 (15.3)
T ₅	Tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	3.8 (14.3)	4.0 (16.1)	3.5 (11.6)	3.8 (14.3)	4.0 (15.7)	4.3 (18.3)	3.8 (14.0)	4.1 (16.1)
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	2.7 (6.7)	3.0 (9.0)	2.9 (8.2)	3.2 (9.9)	3.3 (10.7)	3.4 (11.3)	2.9 (8.0)	3.3 (10.6)
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	3.2 (9.5)	3.3 (10.7)	3.2 (10.1)	3.4 (10.8)	3.8 (13.9)	3.7 (13.6)	3.2 (10.1)	3.6 (12.8)
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topamezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	3.0 (8.5)	3.4 (11.4)	2.9 (8.1)	3.2 (10.1)	3.4 (11.2)	3.6 (12.7)	3.1 (9.4)	3.4 (11.3)
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	3.3 (10.5)	3.5 (12.0)	3.2 (10.0)	3.6 (12.8)	3.5 (12.1)	3.6 (12.8)	3.4 (10.9)	3.6 (12.6)
	Mean	4.8 (32.4)	4.9 (32.2)	4.7 (30.5)	5.2 (37.2)	5.2 (35.4)	5.3 (36.9)		
	Weed management practices (Main)	0.3	0.9	18.4	0.3	1.0	19.1		
	Nutrient levels (Sub)	0.1	NS	10.8	0.1	NS	12.6		
	Weed management practices X Nutrient levels	0.5	NS		0.6	NS			

Note: Data transformed to 'x+0.5 transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

Table 6. Dry weight of total weeds at 90 DAS (g m⁻²) in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14				Mean	2014-15			
		Nutrient Levels (Sub)					Nutrient Levels (Sub)			
		F ₁	F ₂	F ₃	Mean		F ₁	F ₂	F ₃	Mean
T ₁	Weedy check	14.3 (203)	13.4 (179)	13.3 (176)	13.6 (186)	16.5 (271)	15.8 (249)	15.3 (239.0)	15.8 (253)	
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	7.6 (58.3)	7.3 (54.7)	7.1 (52.1)	7.3 (55.0)	8.1 (64.8)	8.4 (70.6)	7.9 (63.9)	8.1 (66.4)	
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	8.3 (69.5)	7.8 (61.6)	9.0 (80.7)	8.4 (70.6)	9.2 (84.2)	8.7 (75.3)	8.9 (79.8)	8.9 (79.7)	
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	7.3 (53.1)	7.3 (52.5)	7.1 (51.6)	7.2 (52.4)	7.4 (54.0)	7.4 (54.1)	7.2 (52.7)	7.3 (53.6)	
T ₅	Tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	7.7 (58.6)	6.8 (46.2)	7.6 (57.9)	7.4 (54.2)	7.7 (59.9)	7.0 (48.7)	7.6 (58.2)	7.4 (55.6)	
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topamezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	4.8 (22.9)	5.6 (31.9)	4.5 (19.8)	5.0 (24.9)	4.8 (23.4)	5.7 (32.5)	4.6 (20.6)	5.0 (25.5)	
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	5.1 (25.3)	5.8 (34.4)	5.1 (26.0)	5.3 (28.6)	5.1 (26.2)	5.9 (34.9)	5.2 (27.2)	5.4 (29.4)	
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topamezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	4.8 (22.6)	5.6 (31.4)	4.9 (24.0)	5.1 (26.0)	4.9 (23.4)	5.7 (32.3)	5.0 (24.5)	5.2 (26.7)	
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	5.5 (29.2)	6.0 (35.2)	5.3 (27.5)	5.6 (30.6)	5.5 (29.9)	6.0 (36.5)	5.3 (27.7)	5.6 (31.4)	
	Mean	7.2 (60.3)	7.3 (58.6)	7.1 (57.3)		7.7 (70.7)	7.8 (70.5)	7.4 (66.0)		
	Weed management practices (Main)	0.4	1.2	18.6		0.5	1.6	21.5		
	Nutrient levels (Sub)	1.8	NS	14.3		0.2	NS	10.7		
	Weed management practices X Nutrient levels	0.7	NS			0.9	NS			

Note: Data transformed to $\sqrt{x+0.5}$ transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

Table 7. Dry weight of total weeds at harvest (g m^{-2}) in maize as influenced by herbicides application

T. No.	Weed management practices (Main)	2013-14			Mean	2014-15			Mean
		Nutrient Levels (Sub)				Nutrient Levels (Sub)			
		F ₁	F ₂	F ₃		F ₁	F ₂	F ₃	
T ₁	Weedy check	16.8 (281.0)	16.6 (277.6)	16.2 (265.7)	16.5 (274.8)	16.0 (257.4)	15.9 (255.0)	16.5 (272.3)	
T ₂	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence	8.5 (73.5)	9.4 (91.2)	8.5 (74.5)	8.8 (79.7)	9.3 (87.1)	8.8 (78.8)	9.0 (81.9)	
T ₃	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence	10.3 (107.6)	9.1 (82.8)	9.7 (93.0)	9.7 (94.5)	9.6 (92.9)	9.8 (98.4)	9.9 (98.0)	
T ₄	Topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	8.1 (65.0)	8.2 (67.5)	7.9 (63.3)	8.1 (65.3)	8.1 (65.3)	8.0 (65.7)	8.3 (69.1)	
T ₅	Tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	8.5 (71.9)	7.5 (56.4)	8.6 (74.1)	8.2 (67.5)	8.2 (67.5)	8.4 (70.1)	8.3 (69.2)	
T ₆	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb topramezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	5.5 (30.1)	6.4 (41.5)	5.2 (26.4)	5.7 (32.7)	6.4 (41.7)	5.4 (28.7)	5.8 (34.1)	
T ₇	Atrazine @ 1.25 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	5.8 (33.2)	6.6 (44.5)	5.9 (34.0)	6.1 (37.2)	6.7 (45.7)	6.0 (35.9)	6.2 (39.0)	
T ₈	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb topamezone @ 25 g ai ha ⁻¹ at 20 DAS as post-emergence	5.5 (29.9)	6.4 (41.0)	5.7 (31.6)	5.8 (34.2)	6.6 (43.8)	5.8 (32.7)	6.0 (35.7)	
T ₉	Pendimethalin @ 0.75 kg ai ha ⁻¹ as pre-emergence fb tembotrione @ 110 g ai ha ⁻¹ at 20 DAS as post-emergence	6.2 (38.0)	6.8 (45.5)	6.0 (35.8)	6.3 (39.7)	6.9 (48.0)	6.1 (37.3)	6.5 (41.8)	
	Mean	8.3 (81.1)	8.6 (83.1)	8.2 (77.6)		8.7 (83.3)	8.3 (78.1)		
	Weed management practices (Main)	0.5	1.6	18.7		1.5	18.1		
	Nutrient levels (Sub)	2.6	NS	16.1		NS	9.6		
	Weed management practices x Nutrient levels	0.9	NS			NS			

Note: Data transformed to $\sqrt{x+0.5}$ transformations. Figures in parenthesis are original values; RDF: Recommended dose of fertilizers; MI: Microbial inoculant

CONCLUSION

Sequential application of herbicides *i.e.*, atrazine @ 1.25 kg a.i ha⁻¹ as pre-emergence followed by topamezone @ 25 g a.i ha⁻¹ at 20 DAS as post-emergence (T₆) found to be superior and recorded lowest weed density and weed dry weight at all stages of crop growth. It can also be inferred that nutrient levels have not shown any impact on weed density and weed dry weight at all stages of crop growth at any stage of crop growth. It was also concluded that there is no interaction effect between weed management and nutrient management treatments.

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GENERATING MARKET INFORMATION AND MARKET OUTLOOK OF MAJOR CASSAVA MARKETS IN AFRICA: A DIRECTION FOR NIGERIA TRADE INVESTMENT AND POLICY

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ABSTRACT

The findings confirmed the presence of cointegration, implying long-run price association among the related markets. For additional evidence as to whether and in which direction price transmission was occurring between the markets pair, Granger causality test indicated four unidirectional causalities: Rwanda-Nigeria; Ghana-Rwanda; Nigeria-Madagascar and Madagascar-Rwanda, while the remaining market pairs showed no causal relation between them. The impulse response functions conducted confirmed the result of cointegration, but the magnitude of price transmission was found relatively low in some market pairs that were spatially integrated. Further, the findings indicated usefulness of cassava trading in the major cassava markets in Africa given that explosive volatility pattern was not observed. ARIMA model could be used successfully for modeling as well as forecasting of yearly prices of cassava in the major markets in Africa given its good performance in terms of explained variability and predicting power. Based on findings, network design for major cassava markets across Africa at almost equal distance from each other to enhance market integration and better price transmission among them was recommended. Also, the high degree of market integration observed in this case indicate that the major cassava markets in Africa were quite competitive, thus, providing little justification for extensive and costly intervention designed to enhance market efficiency *via* improved competition.

INTRODUCTION

Market intelligence is an essential function for the formulation of a sound price and trade policy, and its successful implementation. It serves as a mechanism for understanding the behavior of relevant factors; and helps in the evolution of a proper pricing policy and generating outlook information. Market information creates competitive market process and checks the growth of monopoly or profiteering by individuals. It is the lifeblood of a market, because everyone engaged in production, and in buying and selling of products is continually in need of market information. This is true where agricultural commodities are concerned, because their prices fluctuate more widely than those products of other sectors. The research in agricultural marketing in sub-Saharan Africa, particularly of applied nature, has been meagre and scanty because of the strenuous and time consuming job of collecting and maintaining a credible data from different market functionaries, because in most cases market functionaries are not ready to part with correct information and data, thus,

making marketing research in sub-Saharan Africa not to make headway for long, as such, a lot of scope exists for research in this field. Therefore, there is an urgent need for an analysis of the most relevant variables in marketing research. This research looks into the perspective of cassava marketing in sub-Saharan Africa considering its nascent stage. Examples of studies on cassava marketing are Ibanez *et al.*(2009); Ijiako *et al.*(2013); Kwasi and Kobina (2014), and Ospina-Patino and Ezedinma (2015), but the major drawback is that all these studies focused on domestic marketing of this product; with no evidence based studies on international trade outlook of this commodity despite its emerging market potentials in the world. It is a known fact that the need for research in cassava marketing has been recognized by the planners and policy makers, given that, research in this aspect can contribute to the establishment of facts and evolution of the policy measures that may be necessary for developing a successful marketing strategy with respect to production, consumption, distribution and pricing. A

smooth functioning of the marketing system is essential for price stability and for proper incentives to the producers. In the present context, when agricultural production is on the increase, the marketing system should be suitably altered to sustain the increase by providing efficient and prompt services. This can be achieved by keeping a constant watch on developments and by anticipating the problems in marketing of this commodity. Market information is essential for the government, for creating a policy environment for a smooth conduct of the marketing business, and for the protection of all the groups of persons associated with this. Also, it is essential at all the stages of marketing, from the sale of the produce at the farm until the goods reach the last/final consumer.

MATERIAL AND METHODS

Africa is a continent comprising 63 political territories, representing the largest of the great southward projections from the main mass of Earth's surface. Yearly data on producer cassava prices (\$/ tons) in Ghana, Nigeria, Madagascar and Rwanda markets spanning from 1991 to 2014 were sourced from the FAOSTAT databank. Analytical techniques used are described below:

Empirical Models

1. Model Selection Criteria

The information criteria are computed for the VAR models of the form:

$$Y_t = A_1 Y_{t-1} + \dots + A_n Y_{t-n} + B_q X_t + \dots + B_q X_{t-q} + CD_t + \mathcal{E}_t \dots \dots \dots (1)$$

Where Y_t is K -dimensional. The lag order of the exogenous variables $X_{p,q}$, and deterministic term D_t have to be pre-specified. For a range of lag orders n the model is estimated by OLS. The optimal lag is chosen by minimizing one of the following information criteria:

$$AIC(n) = \log \det \{ \Sigma_u(n) \} + (2/T) nK^2 \dots \dots (2)$$

$$HQ(n) = \log \det \{ \Sigma_u(n) \} + (2 \log \log T/T) nK^2 \dots (3)$$

$$SC(n) = \log \det \{ \Sigma_u(n) \} + (\log T/T) nK^2 \dots (4)$$

$$FPE(n) = (T + n^*/T - n^*)^k \det \{ \Sigma_u(n) \} \dots (5)$$

Where $\{ \Sigma_u(n) \}$ is estimated by $T^{-1} \sum_{t=1}^T U_t U_t'$, n^* is the total number of parameters in each equation of the model when n is the lag order of the endogenous variables, also counting the deterministic terms and exogenous variables. The sample length is the same for all different lag lengths and is determined by the maximum lag order.

2. Augmented Dickey Fuller Test

The Augmented Dickey-Fuller test (ADF) is the test for the unit root in a time series sample (Blay et al., 2015). The autoregressive formulation of the ADF test with a trend term is given below:

$$\Delta p_t = \alpha + \rho_{t-1} + \sum_{j=2}^{it} \beta_j \Delta p_{it-j+t} + \mathcal{E} \dots \dots \dots (6)$$

Where, p_{it} is the price in market i at the time t , Δp_{it} ($p_{it} - p_{t-1}$) and α is the intercept or trend term. The joint hypothesis to check the presence of unit root is: $H_0: \gamma = \alpha_0 = 0$ using ϕ_1 statistic. Failure of the rejection of null hypothesis means that the series is non-stationary.

3. Johansen's Co-integration Test

The Johansen procedure is a multivariate generalization of the Dickey-Fuller test and the formulation is as follows (Johansen, 1988):

$$\rho_t = A_1 \rho_{t-1} + \mathcal{E}_t \dots \dots \dots (7)$$

So that

$$\Delta \rho_t = A_1 \rho_{t-1} - \rho_{t-1} + \mathcal{E}_t \dots \dots \dots (8)$$

$$\rho_t = (A_1 - I) \rho_{t-1} + \mathcal{E}_t \dots \dots \dots (9)$$

$$\Delta \rho_t = \prod \rho_{t-1} + \mathcal{E}_t \dots \dots \dots (10)$$

Where, ρ_t and \mathcal{E}_t are $(n \times 1)$ vectors; A_t is an $(n \times n)$ matrix of parameters; I is an $(n \times n)$ identity matrix; and \prod is the (A_{t-1}) matrix. The rank of (A_{t-1}) matrix equals the number of co-integrating vectors. The crucial thing to check is whether (A_{t-1}) consists of all

zeroes or not. If it does, then it implies that all the $\{p\}$ in the above VAR are unit root processes, and there is one linear combination of which is stationary, and hence the variables are not co-integrated. The rank of matrix Π is equal to the number of independent co-integrating vectors. Both trace and max test were used to determine the presence of co-integrating relationship among and between the price series. Using the estimates of the characteristic roots, the tests for the number of characteristic roots that are insignificantly different from unity were conducted using the following statistics:

$$\lambda_{trace} = -T \sum_{i=r+1}^n \ln(1-\lambda_i) \dots\dots\dots (11)$$

$$\lambda_{max} = -T \ln(1-\lambda_i + I) \dots\dots\dots (12)$$

Where, λ_i denotes the estimated values of the characteristic roots (eigen values) obtained from the estimated Π matrix; and T is the number of usable observations.

4. Granger Causality Test

Granger (1969) causality test was used to determine the order and direction of short-term and long-term equilibrium relationships. Whether market p_1 Granger causes market p_2 or vice-versa was checked using the following model:

$$p_t = c + \sum_{i=1}^n (\phi p_{1t-i} + \delta_i p_{2t-i}) + \varepsilon_i, \dots\dots\dots (13)$$

A simple test of the joint significance of δ_i was used to check the Granger causality, i.e.

$$H_0: \delta_1 = \delta_2 = \dots\dots\dots \delta_n = 0.$$

5. Vector Error Correction Model (VECM)

After establishing the multiple co-integrating relationships among price series, Vector Error Correction Model (VECM) was constructed to determine the short-term disturbances and the adjustment mechanism to estimate the speed of adjustment. The VECM explains the difference in y_t and y_{t-1} (i.e. Δy_t) and it is shown below:

$$\Delta y_t = a + \mu(y_{t-1} - \beta x_{t-1}) + \sum_{i=0}^{i=t} \delta_i \Delta x_{t-1} + \sum_{i=1}^{i=t} \gamma_i \Delta y_{t-1} \dots\dots (14)$$

It includes the lagged differences in both x and y , which have a more immediate impact on the value of Δy_t . For example, if Δx_t increases by one percentage point, then Δy_t would increase by δ percentage point. The value of β indicates the percentage point would change in the long-run in response to changes in x . Therefore, part of the change in Δy_t could be explained by y correcting itself in each period to ultimately reach the long-run path with x . The amount by which the value of y changes (or corrected) in each period is signified by μ . This coefficient (μ) indicates the percentage of the remaining amount that y has to move to return to its long-run path with x . In explaining changes in a variable, the VECM accounts for its long-run relationship with other variables. The advantage of VECM over an ordinary OLS model is that it accounts for dynamic relationships that may exist between a dependent variable and explanatory variable, which may span over several periods.

6. Impulse Response Functions

Granger causality tests do not determine the relative strength of causality effects beyond the selected time span. In such circumstances, causality tests are inappropriate because these tests are unable to indicate how much feedback exists from one variable to the other beyond the selected sample period (Rahman and Shahbaz, 2013; Beag and Singla, 2014). The best way to interpret the implications of the models for patterns of price transmission, causality and adjustment are to consider the time paths of prices after exogenous shocks, i.e. impulse responses (Beag and Singla, 2014). The impulse response function traces the effect of one standard deviation or one unit shock to one of the variables on current and future values of all the endogenous variables in a system over various time horizons

(Sadiq et al., 2016). For this study the generalized impulse response function (GIRF) originally developed by Koop et al. (1996) and suggested by Pesaran and Shin (1998) was used. The GIRF in the case of an arbitrary current shock, δ , and history, ω_{t-1} , is specified below:

$$GIRF_Y(h, \delta, \omega_{t-1}) = E [Y_{t+h} | \delta, \omega_{t-1}] - E [y_{t-1} | \omega_{t-1}] \dots\dots\dots(15)$$

For $n = 0, 1$

7. GARCH Model

The representation of the GARCH (p, q) is given as:

$$Y_t = \alpha + b_1 Y_{t-1} + b_2 Y_{t-2} + \epsilon_t$$

(Autoregressive process) (16)

And the variance of random error is:

$$\sigma_t^2 = \lambda_0 + \lambda_1 \mu_{t-1}^2 + \lambda_2 \sigma_{t-1}^2 \dots\dots\dots (17)$$

$$\sigma_t^2 = \omega + \sum_{i=1}^p \beta_i \sigma_{t-i}^2 + \sum_{j=1}^q \alpha_j \epsilon_{t-j}^2 \dots\dots (18)$$

Where, Y_t is the price in the t^{th} period of the i^{th} market p is the order of the GARCH term and q is the order of the ARCH term. The sum of $(\alpha + \beta)$ gives the degree of persistence of volatility in the series. The closer is the sum to 1; the greater is the tendency of volatility to persist for a longer time. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from the mean value.

8. ARIMA Model

A generalization of ARMA models which incorporates a wide class of non-stationary time-series is obtained by introducing the differencing into the model. The simplest example of a non-stationary process which reduces to a stationary one after differencing is Random Walk. A process $\{y_t\}$ is said to follow an integrated ARMA model, denoted by ARIMA (p, d, q), if $\nabla^d y_t$ ($1-\beta$)^d ϵ_t is ARMA (p, q), and the model is written below:

$$\varphi(\beta) (1-\beta)^d y_t = \theta(\beta) \bar{\epsilon}_t \dots\dots\dots(19)$$

Where, $\epsilon_t \sim WN(0, \sigma^2)$, and WN indicates white noise. The integration parameter d is a non-negative integer. When $d = 0$, ARIMA (p, d, q) = ARMA (p, q).

Forecasting Accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE) and relative mean absolute prediction error (RMAPE) were computed using the following formulae (Paul, 2014):

$$MAPE = 1/T \sum \{A_t - F_t\} \dots\dots\dots (20)$$

$$RMPSE = 1/T \sum \{(A_t - F_t)^2 / A_t\} \dots\dots (21)$$

$$RMAPE = 1/T \sum \{(A_t - F_t) / A_t\} \times 100 \dots (22)$$

Where, A_t = Actual value; F_t = Future value, and T = Time period(s)

RESULTS AND DISCUSSION

Summary statistics of yearly producer prices of cassava in major cassava markets in Africa

The summary statistics of yearly prices of cassava spanning from 1991 to 2014 are presented in Table 1. The perusal of Table 1 reveals that the minimum values of the average prices varied from \$38.96 per ton in Ghana market to \$120.77 per ton in Nigeria market, while the maximum values of the average prices varied from \$200.00 per ton in Madagascar market to \$541.90 per ton in Nigeria market during the period under consideration. The average prices per ton were found to be \$111.99 in Ghana market, \$219.78 in Nigeria market, \$130.13 in Madagascar market and \$228.30 in Rwanda market. The standard deviation in prices was found to be minimum in Madagascar market (\$40.99 per ton) and maximum in Nigeria market (\$122.70 per ton) during the period under consideration. Slight instability in cassava prices were noticed in all the selected markets, with it being highest in Nigeria market during the period under consideration, which might be due to fluctuation in arrivals as a result of seasonality. All the selected markets exhibited positively skewed distribution in their respective

prices from year 1991 to 2014. Almost all the selected markets showed a platykurtic (fat or short-tailed) probability distribution function except Nigeria market

which showed a leptokurtic (slim or long-tailed) pattern of distribution for the entire period under consideration.

Table 1. Summary statistics of yearly producer prices of cassava in major cassava markets in Africa (\$ per ton)

Market	Min	Max	Mean	STD	CV	Skewness	Kurtosis	IQ range
Ghana	38.96	210.00	111.99	50.71	0.45	0.36	-1.02	82.94
Nigeria	120.77	541.90	219.78	122.70	0.55	1.83	1.96	63.79
Madagascar	65.41	200.00	130.13	40.99	0.31	0.13	-1.28	74.12
Rwanda	79.78	368.81	228.30	87.12	0.38	0.011	-1.29	158.43

Lag Selection Criteria

Because of sensitivity of time series to lag length and to ensure that errors are white noise in ADF, the information criteria *viz.*, Akaike information criterion (AIC), Hannan–Quinn criterion (HQC) and Schwarz Bayesian criterion (BIC) were used to select appropriate lag length for the analyses. The test results as shown in Table 2 reveal that the

optimum lag length appropriate for the specified variables is lag 2 as indicated by the asterisks among the information criteria. This means that the optimum lag length for the series should be lag 2 in order to obtain more interpretable parsimonious models. However, it should be noted that when all the selection criteria agree, the selection is clear, but in a situation of conflicting results, the selection criteria with the highest lag order is considered.

Table 2. Lag selection criteria

Lag(s)	AIC	BIC	HQC
1	41.06	42.05	41.29
2	40.67*	42.45*	41.09*

Unit Root Test

To investigate the market integration, Augmented Dickey Fuller (ADF) test for unit root test was conducted and the results shown in Table 3. The ADF values of all the series were non-significant at 5 per cent level of significance, indicating the existence of unit root in the series; implying non-stationary nature of the data, but at first difference level, the ADF values for all the series were significant at 5 percent level of significance, implying that these price series were free from the consequences of unit root; meaning that the price series were stationary

at first difference. ADF-GLS test, which provides an alternate method for correcting serial correlation and heteroscedasticity, was used to validate the results. The results of the unit root test did not reject the null hypothesis of presence of unit root when the series were considered at level. The first differenced series were found to be stationary, *i.e.*, these are integrated of order one. Having ensured I(1) of the price series, the relationship between these markets was estimated using the co-integration test; the conformation that each level series is I(1) allowed to proceed for Johansen’s cointegration test.

Table 3. Unit roots test with constant and trend

Market	Stage	ADF T-stat	P<0.05	ADF-GLS		Remarks
				T-stat	T-critical (5%)	
Ghana	Level	-0.87	0.9573	-1.17	-3.19	Non-stationary
	1 st Difference	-8.10**	8.9E-013	-6.45**	-3.19	Stationary
Nigeria	Level	-3.31	0.06365	-2.43	-3.19	Non-stationary
	1 st Difference	-4.32**	0.01265	-4.47**	-3.19	Stationary
Madagascar	Level	-2.18	0.476	-1.47	-3.19	Non-stationary
	1 st Difference	-6.95**	5.466E-005	-7.31**	-3.19	Stationary
Rwanda	Level	-2.59	0.2838	-2.70	-3.19	Non-stationary
	1 st Difference	-4.54**	0.0012	-4.97**	-3.19	Stationary

Note: ** indicate that unit root at level or at first difference was rejected at 5 per cent significance.

Johansen's Multiple Co-integration Test

To determine the long-run relationship between the price series from a range of four price series, Johansen's co-integration test was employed and test revealed only two co-integrating equations for the four selected markets, indicating that there is one stochastic trend present in the system, and also the selected cassava markets is likely to exhibit long-run equilibrium relationship. Both tests (Trace and max tests) confirmed that all the selected cassava markets had 2 cointegrating vectors out of 4

cointegrating equations, indicating that they are efficient, well integrated and price signals were transferred from one market to the other to ensure efficiency. Thus, Johnson cointegration test has shown that even though the selected cassava markets in Africa were geographically isolated and spatially segmented, they were well-connected in terms of prices of cassava, demonstrating that the selected cassava markets have long-run price linkage across them (Table 4).

Table 4. Multiple cointegration result

H_0	H_1	Eigen value	Trace test	P-value	Lmax test	P-value
$r = 0$	$r \leq 1$	0.79383	71.277*	0.0001	33.160*	0.0064
$r \leq 1$	$r \leq 2$	0.66397	38.116*	0.0038	22.902*	0.0256
$r \leq 2$	$r = 3$	0.39967	15.215	0.0536	10.716	0.1716

Note: *denotes rejection of the null hypothesis at 5 per cent level of significance

However, the integration of cassava prices between market pair was tested using Johansen's Cointegration test. Results showed that Ghana market was not cointegrated with Madagascar and Rwanda markets, but co integrated with Nigeria market despite this market pair being far apart

geographically; Nigeria market was co integrated with Madagascar and Rwanda markets despite being far apart; and, Madagascar market was not co integrated with Rwanda market (Table 5). Therefore, it could be inferred that cassava markets in pair-wise were to certain extent integrated within Africa.

Table 5. Pair-wise co integration

Market pair	H_0	H_1	Trace test	P-value	Lmax test	P-value	CE
Ghana–Nigeria	$r = 0$	$r \geq 1$	17.724	0.0051	13.204	0.0206	1CE
	$r \leq 1$	$r \geq 2$	4.5195	0.0381	4.5195	0.0398	
Ghana–Madagascar	$r = 0$	$r \geq 1$	13.198	0.0347	9.893	0.085	NONE
	$r \leq 1$	$r \geq 2$	3.305	0.0801	3.305	0.082	
Ghana–Rwanda	$r = 0$	$r \geq 1$	13.786	0.0273	8.827	0.130	NONE
	$r \leq 1$	$r \geq 2$	4.959	0.0292	4.959	0.0308	
Nigeria– Madagascar	$r = 0$	$r \geq 1$	17.941	0.0046	12.390	0.0295	1CE
	$r \leq 1$	$r \geq 2$	5.551	0.0205	5.551	0.0219	
Nigeria– Rwanda	$r = 0$	$r \geq 1$	19.242	0.0026	14.354	0.0122	1CE
	$r \leq 1$	$r \geq 2$	4.887	0.0305	4.887	0.0321	
Madagascar–Rwanda	$r = 0$	$r \geq 1$	13.395	0.0320	8.953	0.1237	NONE
	$r \leq 1$	$r \geq 2$	4.4412	0.0399	4.441	0.0417	

Note:*denotes rejection of the null hypothesis at 5% level of significance

CE- Co integration Equation

Vector Error Correction Model

Johansen's test showed there is a long-run association between these markets, thus, justifying the use of a vector error correction model (VECM) to capture the short-run dynamics. The application of VECM indicated estimated coefficients of three markets to be negative and statistically significant (Table 6). The vector error correction (VEC) coefficients were -0.13, -0.74 and -0.21 for Ghana, Nigeria and Madagascar, respectively. This indicates how fast the dependent variables for Ghana, Nigeria and Madagascar markets with respect to prices absorbed and adjusted themselves for the previous period disequilibrium errors. In other words, the VEC coefficients measure the ability of these markets to incorporate shocks or speculations in the prices. In this case, Ghana, Nigeria and Madagascar markets absorbed 13 per cent, 74 per cent and 21 per cent, respectively to move towards equilibrium in the prices. The information flow was more in Ghana market as is evident from the magnitude of the VEC

coefficient (0.13). In other words, the prices of cassava in Ghana, Nigeria and Madagascar markets were sensitive to departure from their equilibrium states or levels in the previous periods. For Ghana, Nigeria and Madagascar markets, the slope coefficients of the error correction term were 0.13; 0.74; 0.21 respectively, representing the speed of adjustment, and also consistent with the hypotheses of convergence towards the long-run equilibrium once the price equations were disturbed. This means that, it will take Ghana, Nigeria and Madagascar markets about 1 month 17 days; 8 months 26 days and 2 months 16 days, respectively, to adjust fully to equilibrium position in the long run due to disturbances in the marketing system in the study area *i.e.*, these markets are above the equilibrium and it will take approximately 1 month 17 days; 8 months 26 days and 2 months 16 days in Ghana, Nigeria and Madagascar markets, respectively, to correct equilibrium errors. The empirical results revealed that the long run models of cassava prices for Ghana, Nigeria and Madagascar markets in Africa

converged to the postulate of the law of one price. The constant terms in the three long run equations gave the picture of the transfer cost or the extent of price differential which were due to arbitrage activities. The results further revealed the insignificant influence of the transfer cost in the marketing process of cassava in Rwanda market, perhaps suggesting high efficiency in information transmission between Rwanda market and other markets, and improvement in the marketing infrastructure in Rwanda market. However, the coefficient of Vector Error correction term for Rwanda market was negative but non-significant.

The effects of lagged prices in the selected markets were negative as well as positive, suggesting that, in the short-run, price shocks were contemporaneously transmitted in these markets but not fully. In Ghana market, its own lagged prices

and lagged prices in Nigeria market tend to affect it; in Nigeria market, its own lagged prices and lagged prices of Madagascar market tend to affect it; in Madagascar market, lagged prices of Nigeria market and its own lagged prices tend to affect it; and in Rwanda market, only lagged prices of Ghana market affect it. In other words, the short-run dynamics indicates that one year lagged prices in the related market prices were transmitted to the current prices. To strength the linkage and interconnectedness among these selected markets for faster transmission of price and management of commodity from surplus area to deficit area, the clarion call is to enhance the development of market infrastructure, use of information and technology in transaction of goods (COMEXB), processing, transportation and other back-end supply chain of cassava. This would definitely help in the development of single integrated economic market for cassava in Africa.

Table 6. Vector Error Correction Model of major cassava markets in Africa

Variable	D(Ghana)	D(Nigeria)	D(Madagascar)	D(Rwanda)
ECT	-0.1296	-0.7399	-0.2089	0.0615
	(0.0496)	(0.2312)	(0.054)	(0.1510)
	{-2.609} ^{**}	{-3.200} ^{***}	{-3.852} ^{***}	{0.407} ^{NS}
D(Ghana)	0.378	0.389	0.1814	-1.204
	(0.2086)	(0.972)	(0.0728)	(0.6346)
	{1.813} [*]	{0.401} ^{NS}	{0.796} ^{NS}	{-1.897} [*]
D(Nigeria)	0.175	0.688	0.2648	0.3147
	(0.0667)	(0.311)	(0.0728)	(0.2028)
	{2.619} ^{**}	{2.214} ^{**}	{3.637} ^{***}	{1.552} ^{NS}
D(Madagascar)	-0.274	-2.076	-0.8069	-0.783
	(0.1690)	(0.787)	(0.1846)	(0.514)
	{-1.619} ^{NS}	{-2.637} ^{**}	{-4.371} ^{***}	{-1.522} ^{NS}
D(Rwanda)	0.084	-0.0075	-0.0701	0.1943
	(0.1054)	(0.491)	(0.1151)	(0.3204)
	(0.799) ^{NS}	{-0.015} ^{NS}	{-0.6091} ^{NS}	{0.6063} ^{NS}
Constant	26.22{2.817} ^{***}	148.64{3.429} ^{***}	-28.56{-2.81} ^{**}	21.277{0.7515} ^{NS}

Note: ^{***}, ^{**}, ^{*} implies significance at 1%, 5% and 10%, respectively

NS: Non-significant; () ; { } implies standard error and t-statistic

Granger Causality Test

After determining cointegration among different cassava markets, Granger causality was also estimated between the selected pairs of cassava markets in Africa. The Granger causality shows the direction of price formation between two markets and related spatial arbitrage, *i.e.*, physical movement of the commodity to adjust the prices difference. The results of Granger causality tests showed that all the three F-statistics for the causality tests of producer prices in Nigeria market on other markets were not statistically significant, thus, the null hypothesis of no Granger causality was accepted in each case for Nigeria market. Besides, Madagascar market had two, while Ghana and Rwanda markets each had one F-statistics statistically significant on other market prices (Table 7).

According to the Granger causality tests, there were unidirectional causalities between these

market pairs: Rwanda-Nigeria, Ghana-Rwanda; Madagascar-Nigeria and Madagascar-Rwanda markets, meaning that a price change in the former market in each pair Granger causes the price formation in the latter market, whereas the price change in the latter market was not fed back by the price change in the former market in each pair. Bi-directional causality was not observed, thus, indicating there was no perfect price transmission mechanism between any cassava market pair. Further, two market pairs, Ghana-Nigeria and Madagascar-Ghana have no direct causality between them, indicating that neither the former in each market pair Granger causes the price formation in latter, nor the latter in each market pair granger causes the price formation in the former. In other words, there was no long-run price transmission between these market pairs.

Table 7. Pair wise Granger causality tests of selected markets

H ₀	T-stat	Prob.	Granger cause	Direction
Ghana → Nigeria	0.754	0.490	No	None
Ghana ← Nigeria	0.098	0.907	No	
Madagascar → Ghana	0.284	0.757	No	None
Madagascar ← Ghana	0.486	0.626	No	
Nigeria → Rwanda	0.961	0.408	No	Unidirectional
Nigeria ← Rwanda	7.769	0.006**	Yes	
Rwanda → Ghana	1.999	0.175	No	Unidirectional
Rwanda ← Ghana	6.103	0.014**	Yes	
Madagascar → Nigeria	4.296	0.037**	Yes	Unidirectional
Madagascar ← Nigeria	2.460	0.124	No	
Rwanda → Madagascar	1.196	0.333	No	Unidirectional
Rwanda ← Madagascar	11.145	0.005**	Yes	

Note: **denotes rejection of the null hypothesis at 5% level of significance

VECM Diagnostic checking

Autocorrelation tests for all the selected markets indicate that the residuals are free from serial correlation as evident from Ljung-Box Q-statistics which are not different from zero at 5 per cent probability level, meaning that the residuals are purely random. Also, the Arch effects indicate that the error term have no arch effects as evident from the LM

test statistics which are not different from zero at 5 per cent probability level. The tests of normality indicate that the residuals are normally distributed as is clear from Doornik-Hansen test which is not different from zero at 5 per cent probability level. Therefore, it can be inferred that the model used certified all the necessary criteria for it to be termed best fit (Table 8).

Table 8. VECM Diagnostic checking

Test		Statistic	P-value
Autocorrelation	Ljung-Box Q (Eq1)	4.872	0.0875
	Ljung-Box Q (Eq2)	0.761	0.684
	Ljung-Box Q (Eq3)	0.274	0.872
	Ljung-Box Q (Eq4)	0.168	0.92
Arch effect	LM-Test (Eq1)	2.594	0.273
	LM-Test (Eq2)	3.256	0.196
	LM-Test (Eq3)	1.452	0.484
	LM-Test (Eq4)	0.517	0.772
Normality	Doornik-Hansen test	11.038	0.1996

Impulse Response Functions

The results of impulse response functions show how and to what extent a standard deviation shock in one of the cassava markets affects the current as well as future prices in all the integrated markets over a period of ten years. When the effect of a shock dies out over time, the shock is said to be transitory and when the effect of a shock does not die out over time, the shock is said to be permanent. It can be observed that when a standard deviation shock is given to any market, the effects on other markets will either be permanent or transitory *i.e.* the responses of other markets appear or disappear between second and tenth years.

The graphs indicate that an orthogonalized shock to the prices in Ghana market will have permanent effect on the prices in Rwanda market and transitory effects on the prices in Nigeria and

Madagascar markets; while an orthogonalized shock to the prices of cassava in Nigeria market will exert transitory effects on Ghana and Madagascar markets, and a permanent on the price in Rwanda market. According to this model, unexpected shocks that are local to Madagascar market will have permanent effects on the prices in Ghana and Nigeria markets, and a transitory effect on Rwanda market; while unexpected shock that are local to Rwanda market would have only permanent effects on the prices in Ghana, Nigeria and Madagascar markets. A shock originating from the Ghana market would be less transmitted to Nigeria and Madagascar markets, and more transmitted to Rwanda market, but a shock originating from Nigeria and Madagascar market would be relatively less transmitted to Ghana market, and relatively more transmitted to Ghana market if the shock originates from Rwanda market. Like Ghana market, a shock given to the Nigeria

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market would be transmitted to a lesser extent to other markets except Rwanda market, implying that Ghana and Nigeria markets would be relatively market followers and will not play a significant role in international cassava markets of Africa. An important point to be noted is that the producer prices in the Madagascar market is positively related to prices in Ghana and Nigeria markets and inversely

related to the prices in the Rwanda market. On the other hand, the results of Rwanda market impulse response confirm that the price transmission from Rwanda to other markets occur in large proportions, thus, implying that the Rwanda market has dominance in price determination in other cassava markets (Fig. 1).

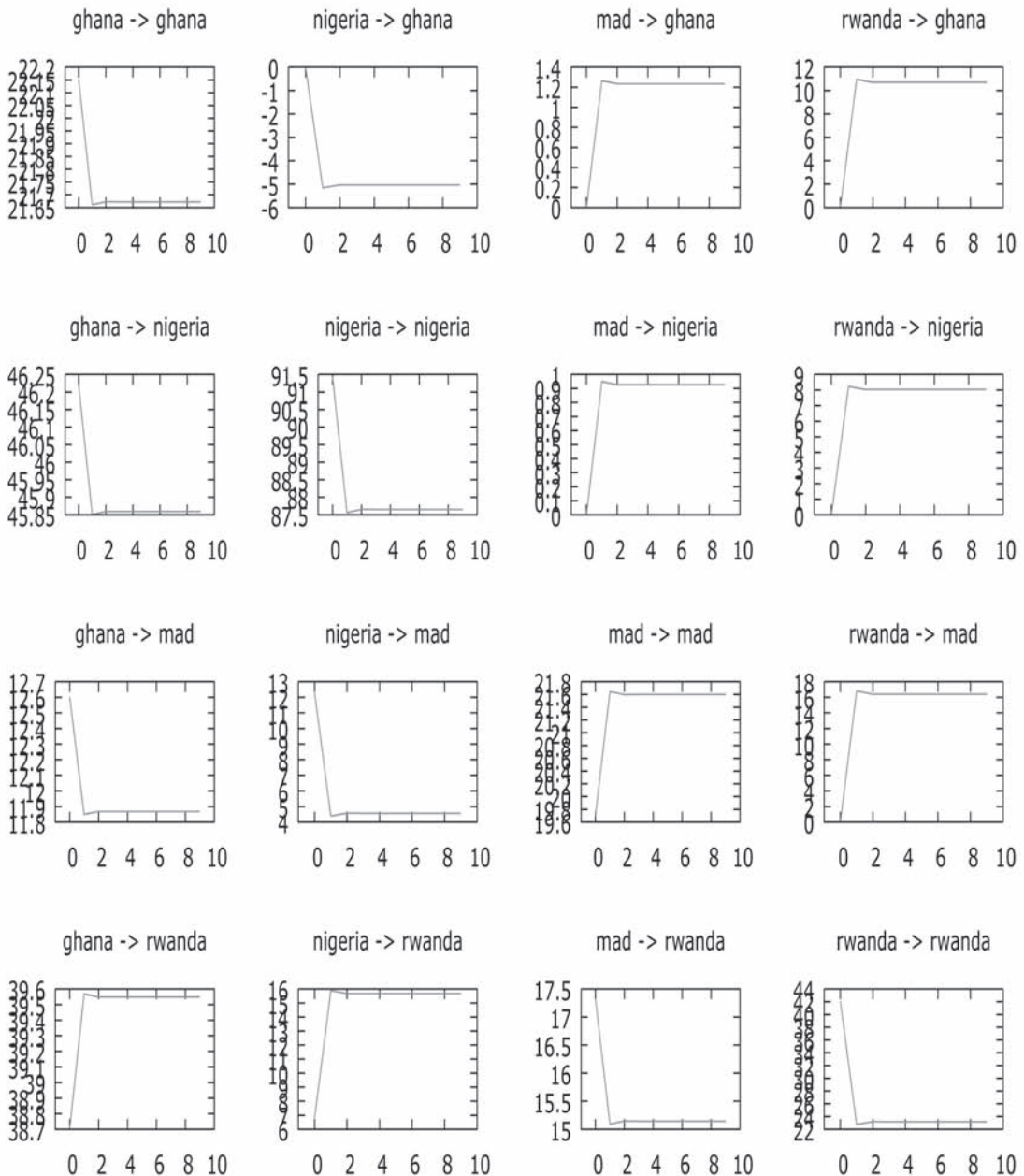


Fig. 1. Impulse response functions

Extent of price volatility in cassava markets

The results of GARCH model have indicated that GARCH order (1,1) fit different markets and was found to be the highest order for the entire period (Table 9). The results further indicated that the estimated sum coefficients of alpha and beta for all the markets were closer to unity, indicating the persistence of volatility in cassava prices of selected markets. The results of GARCH analyses indicated that volatility in the current year prices in all the selected markets depends on information about volatility in the

preceding year prices, which are evident from the significance ARCH-terms. For the entire period, volatility in the current year prices in all the selected markets were not influenced by volatility in prices during the preceding year, as found from non-significant GARCH terms. As expected, none of the series showed an 'explosive' pattern as the values of $(\alpha_i + \hat{\alpha}_i)$ did not exceed one, which infers the usefulness of cassava trading in Africa. The reason for persistence of volatility in prices in all the selected markets could be due to nascent stage of cassava marketing at international level.

Table 9. Estimates of GARCH model for measuring volatility in prices of cassava from 1991-2014

Particulars	Ghana market	Nigeria market	Madagascar market	Rwanda market
Family shocks				
Constant	98.15(1.13E-038) ^{***}	-	-	-
Alpha (0)	227.59(0.562) ^{NS}	12836.8(1.43) ^{NS}	2435.97(1.495) ^{NS}	15471.5(2.399) ^{**}
Alpha (1)	0.61(1.68) [*]	0.874(2.092) ^{**}	0.787(3.187) ^{***}	0.825(3.305) ^{***}
Beta (1)	0.37(0.996) ^{NS}	1.55E-012 (1.009E-011) ^{NS}	0.141(0.681) ^{NS}	5.07E-011(1.00) ^{NS}
Log likelihood	-123.83	-163.39	-150.95	-164.59
GARCH fit	1,1	1,1	1,1	1,1
$\alpha + \beta$	0.98	0.874	0.928	0.825

Notes: Figures within the parentheses indicate the calculated t-statistic

^{***}, ^{**} and ^{*} indicate the significance at 1%, 5% and 10% probability levels, respectively

NS: Non-significant

GARCH Diagnostic checking

Autocorrelation tests for all the selected markets indicate that the residuals are purely random as seen from the Q-statistics which are not different from zero at 5% probability level. Tests of normality

for all the selected markets indicate that the residuals are not normally distributed as understood from the chis -square which are different from zero at 5% probability level (Table 10). However, normality test is not considered a serious matter because in most cases data is not normally distributed.

Table 10. Diagnostic checking for GARCH

Model	Market	ARCH-LM Test	Normality Test (Chi ²)
GARCH	Ghana	0.7433 (0.989)	2.81 (0.000)
	Nigeria	0.5809 (0.559)	43.7 (0.000)
	Madagascar	0.5312 (0.943)	3.06 (0.002)
	Rwanda	0.3836 (0.180)	2.73 (0.000)

Note: Values in parentheses are probability

Forecasting using ARIMA

Various combinations of the ARIMA models were tried after first differencing of all the four series and based on the smallest AIC value; the best ARIMA model was selected. Among all the ARIMA models tested,

ARIMA (0,1,1) model have the minimum AIC values for price series of Ghana; Nigeria and Rwanda markets, while ARIMA (1,1, 0) model has minimum AIC value for Madagascar market price series (Table 11a).

Table 11a. AIC values of different ARIMA models

Market	Criteria	1,1,1	1,1,0	0,1,1
Ghana	AIC	213.8948	217.6009	211.9551**
	BSC	218.4367	221.0074	215.3616
Nigeria	AIC	286.3866	284.3922	284.3897**
	BSC	290.9286	287.7987	287.7962
Madagascar	AIC	229.0783	227.0941**	227.8623
	BSC	233.6203	230.5006	231.2688
Rwanda	AIC	261.8691	261.0318	260.9208**
	BSC	265.2755	260.3028	263.1918

Note: **denotes best ARIMA model

Out of total 23 data points (1991 to 2014), first 18 data points (from 1991 to 2009) were used for model building and the remaining 5 data points (from 2010 to 2014) were used for model validation. One-step ahead forecasts of producer prices for all the selected

markets along with their corresponding standard errors using naïve approach for the period 2009 to 2014 (total 5 data points) in respect of above fitted models were computed (Table 11b).

Table 11b. One step ahead forecast of prices

Date	Ghana market		Nigeria market		Madagascar market		Rwanda market	
	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast
2010	168.95	156.58	142.45	113.93	172.44	184.65	312.27	314.33
2011	176.96	170.58	142.91	141.63	168.08	178.11	265.85	312.53
2012	184.00	183.89	152.55	141.24	170.00	174.94	297.21	271.84
2013	196.00	191.22	161.68	151.19	179.00	174.31	368.81	293.95
2014	210.00	201.70	171.00	160.30	200.00	180.44	337.23	359.20

The forecasting ability of ARIMA (0,1,1) models of price series for Ghana, Nigeria and Rwanda markets; and forecasting capability of ARIMA (1,0,1) model for Madagascar market price series were judged on the basis of mean absolute prediction error

(MAPE), relative mean absolute prediction error (RMAPE) and root mean square error (RMSE) values (Table 11c). A perusal of Table 11c reveals that for all the price series for all the selected markets, RMAPE values were less than 10 per cent, indicating the accuracy of the models used in the study.

Table 11c. Validation of models

Market	MAPE	RMSPE	RMAPE (%)
Ghana	6.388	0.31608	3.48
Nigeria	12.46	1.582	8.22
Madagascar	0.586	0.729	0.711
Rwanda	5.904	5.4004	0.820

One step ahead out of sample forecast of producer prices of cassava for the above four markets during the periods 2015 to 2024 were computed. The forecast values along with their corresponding lower and upper 95 per cent confidence intervals are given in Table 11d and Fig.2. As indicated, cassava prices in Nigeria and Rwanda markets will be volatile during the periods from 2014 to 2024, as reflected by the wider confidence intervals associated with the ARIMA forecasts during this period. These imply that the confidence intervals associated with the one-step-ahead out of sample forecasts during this period are

relatively large. Alternatively, while the confidence intervals of cassava price forecasts for Ghana and Madagascar markets do fluctuate, they tend to be more stable relative to the forecasts intervals for Nigeria and Rwanda markets. These imply the confidence intervals associated with the one-step ahead out of sample forecasts during these periods are relatively smaller. This, in part, might reflect the relatively constant growth of the cassava production during the period 2015 to 2024. The fitted models along with the predicted data points are also depicted in figures 2-5 to visualize the performance of fitted models.

Table 11d. Out of sample forecast of cassava prices in selected markets

Year	Ghana market			Nigeria market		
	Forecast	Upper CL	Lower CL	Forecast	Upper CL	Lower CL
2015	215.08	262.16	168.00	169.62	371.15	102.82
2016	222.91	280.18	165.64	167.91	457.39	147.69
2017	229.89	298.11	161.68	166.20	522.54	121.81
2018	237.13	314.12	160.15	164.49	576.99	110.47
2019	244.29	329.33	159.26	162.78	624.67	135.66
2020	251.48	343.81	159.15	161.07	667.55	158.41
2021	258.66	357.77	159.55	159.36	706.81	129.32
2022	265.84	371.29	160.39	157.65	743.21	128.76
2023	273.02	384.45	161.59	155.94	777.28	117.02
2024	280.20	397.30	163.10	154.23	809.40	134.28
Year	Madagascar market			Rwanda market		
	Forecast	Upper CL	Lower CL	Forecast	Upper CL	Lower CL
2015	196.57	254.34	138.80	340.05	466.38	213.72
2016	203.05	270.25	135.85	340.05	507.63	172.47
2017	205.51	285.75	125.28	340.05	540.56	139.54
2018	209.60	299.25	119.96	340.05	568.81	111.29
2019	213.03	311.84	114.23	340.05	593.93	129.53
2020	216.73	323.67	109.79	340.05	616.78	141.19
2021	220.32	334.91	105.73	340.05	637.88	151.96
2022	223.96	345.68	102.23	340.05	657.58	162.01
2023	227.57	356.05	99.09	340.05	676.13	171.47
2024	231.19	366.08	96.31	340.05	693.71	180.44

Note: CL- Confidence Level

ARIMA Diagnostic Checking

The model verification is concerned with checking the residuals of the model to see if they contained any systematic pattern which still could be removed to improve the chosen ARIMA. The results of autocorrelation tests for all the selected markets indicate that the residuals are purely random as evidence from the Ljung-Box Q-statistics which are not significantly different from zero at 5 percent

probability level (Table 12). This proved that the selected ARIMA (0,1,1) model for price series of Ghana, Nigeria and Rwanda markets; and ARIMA (1,1,0) model for Madagascar market were appropriate model for forecasting. Also, the ARCH effect tests showed no arch effects in the residuals as evident from Lagrange multiplier test which is not different from zero at 5 percent probability level. The normality tests for all the selected markets indicate

that the residuals are not normally distributed as observed from the Chi- square values which are significantly different from zero at 5% probability level (Table 12). However, normality test is not considered

as a serious matter because in most cases data are not normally distributed. Therefore, the selected models were the best fit.

Table 12. Diagnostic checking for best ARIMA models

Market	ARIMA model	Autocorrelation test (Ljung-Box Q)	Arch test (LM)	Normality Test (Chi ²)
Ghana	0,1,1	2.577(0.108)	2.939 (0.230)	0.414 (0.000)
Nigeria	0,1,1	0.0993 (0.753)	0.451(0.798)	13.16 (0.0014)
Madagascar	1,1,0	0.0358 (0.850)	4.715 (0.095)	2.895 (0.000)
Rwanda	0,1,1	2.982 (0.084)	2.702 (0.259)	6.511(0.038)

CONCLUSIONS

The study investigated cointegration, causality, price transmission, price volatility and price forecasts among major cassava markets in Africa. ADF tests results indicated that all the price series were integrated of order 1. The results indicated that different cassava markets in Africa were well-integrated and have long-run price association across them. The market pair-wise cointegration test confirmed that all the market pairs did not have any price association between them, indicating that the major cassava markets in Africa were poorly integrated when considered pair-wise. Some inferences were drawn from the market integration: Price transmission occurred due to the flow of market information which was consequence of development in information technologies; the speed of convergence depends on the market regulations and policy changes; and market integration is an indicator of efficient functioning of markets. VECM results indicate that Ghana, Nigeria and Madagascar markets were above the equilibrium, and it will take approximately 1 month 17 days; 8 months 26 days and 2 months 16 days, respectively to correct their respective equilibrium error. Also, Granger causality tests showed only four market pairs had unidirectional causalities, while all the remaining

market pairs had no causal direction on price formation between them. Situation of market pair bidirectional causality was not observed between the major cassava markets in Africa. Further, results of impulse response functions confirmed that the speeds as well as magnitude of shocks given to Ghana and Nigeria markets were relatively less transmitted to other markets, thus indicating these markets to be trend followers rather than trend setters. This implies that the geographical situation and optimal distance between the market places hold the mutual forces on commodity movements and price formation. Therefore, the researchers advocate that the network of agricultural producer markets should be well-designed so as to keep equal distance from each other, because it will not only boost a direct inter-market competition, but will also control the massive/high marketing margins of agricultural commodities. The produce can be moved to the deficit areas thereby providing benefits to both producers and consumers. The extent of volatility in current prices due to family or internal shocks, as measured by the coefficients of GARCH model, indicated persistence volatility in all the markets, but not of the explosive type, thus indicating usefulness of cassava trading in Africa. Lastly, findings revealed that the ARIMA model could be used successfully

MARKET INFORMATION AND MARKET OUTLOOK OF CASSAVA MARKETS IN AFRICA

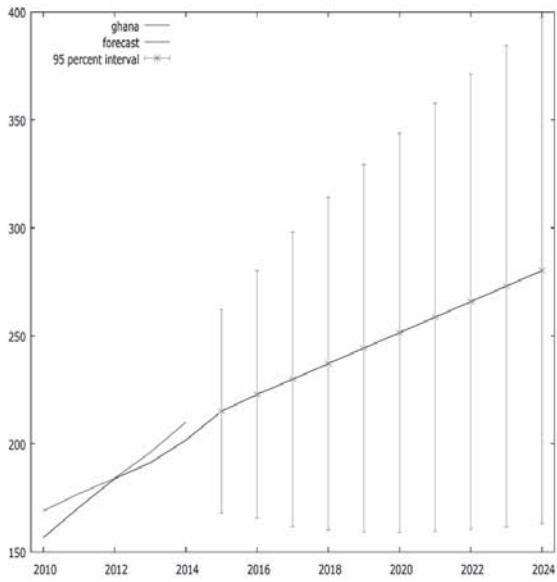


Figure 2: Price forecasts of cassava in Ghana market

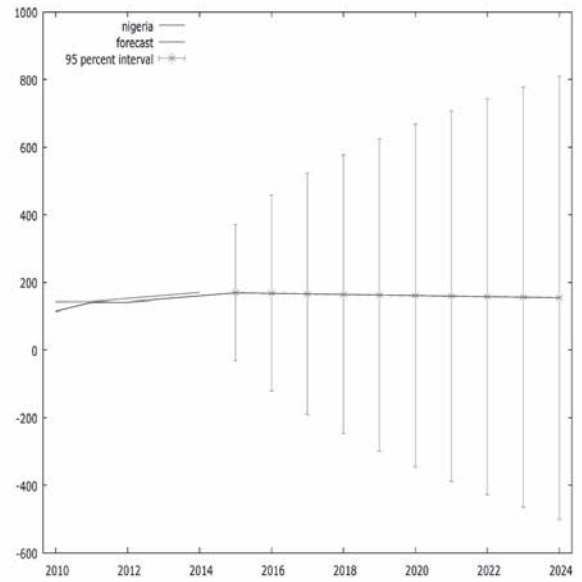


Figure 3: Price forecasts of cassava in Nigeria market

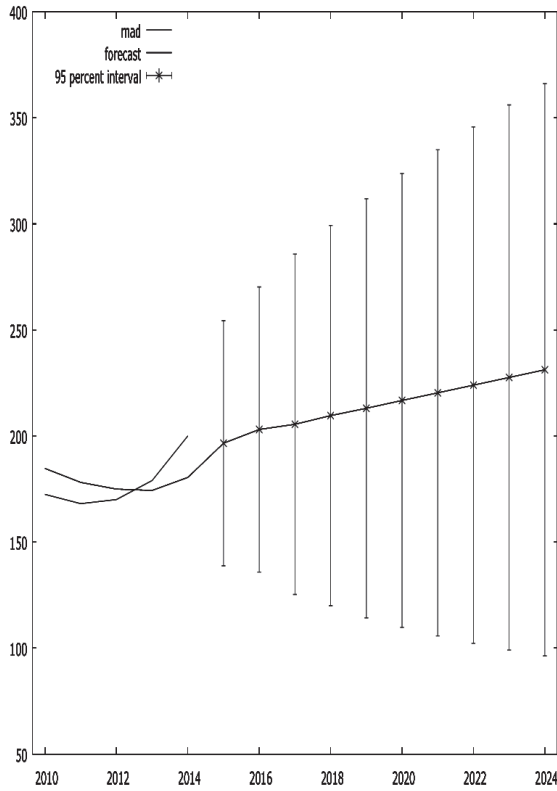


Figure 4: Price forecasts of cassava in Madagascar market

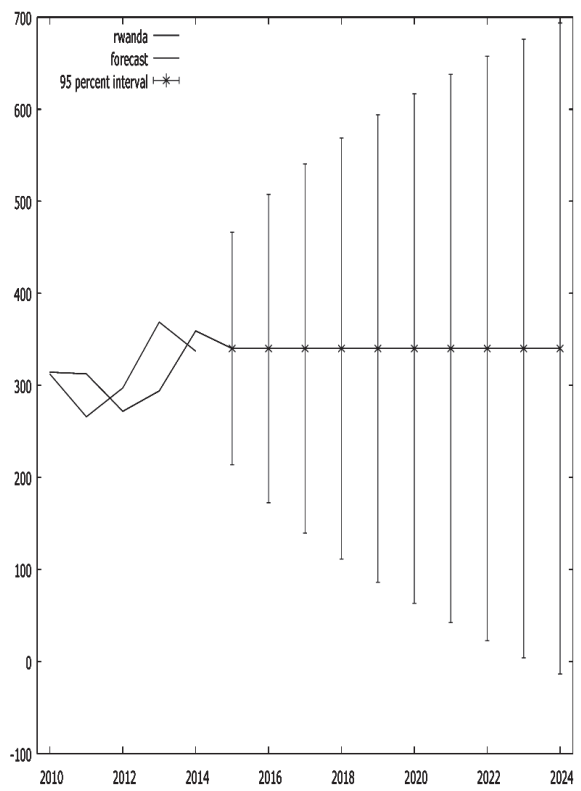


Figure 5: Price forecast of cassava in Rwanda market

for modeling as well as forecasting of yearly producer price of cassava in major cassava markets in Africa, given that the model has demonstrated a good performance in terms of explained variability and predicting power. The findings of the present study will serve as direct support for the potential use of accurate forecasts in decision-making for farmers, middlemen as well as consumers.

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CONSERVATION OF TRADITIONAL RICE VARIETIES FOR CROP DIVERSITY IN KERALA

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ABSTRACT

Despite the declining area and production under rice in Kerala over the past decade, a positive growth trend in productivity is witnessed due to High Yielding Varieties (HYVs). The main objective of this study is to compare the social, economic, management and sustainability aspects of traditional varieties and HYVs of rice in general and to study their performance under the unique ecosystem of *Pokkali*, in Kerala. The tremendous decline in area of traditional varieties (-17.21%), reflected in the output (-17.79%), dropping their productivity from 1842 tonnes per ha to 1645 tonnes per ha. On comparison, highest productivity was seen for HYVs under irrigation (3845 kg ha⁻¹) and the lowest productivity for traditional varieties (TVs) under rainfed condition (1522 kg ha⁻¹). The results confirm the hypothesis that HYVs have a significant positive influence on the crop yield. When 1.38 per cent higher yield is estimated due to the adoption of HYVs, the risk is also high, 7.08 for HYVs and 6.12 per cent for TVs. Still, some personal and economic attributes encourage the continued adoption of TVs, in small and marginal farm holdings. This facilitates developing effective policy for *in-situ* conservation of indigenous land races ensuring local participation. The strategies may include market/legal instruments or efforts in creating awareness and incentivizing the conservation efforts.

INTRODUCTION

For cultivated crops, conservation *insitu* means continued cultivation and management by farmers of crop populations in the agro systems where the crop has evolved. There are global efforts on conservation of traditional resources and wisdom.

The public and private sector investment towards this goal is growing in India as well. India has made significant progress in setting up a regime for the management of its plant genetic resource (Biber-Klemm *et al.*, 2005). India was endowed with more than two lakh rice varieties, with Kerala as one of the centres of diversity of rice. The antiquity of rice cultivation in the state dates back to 3000 BC (Manilal, 1990). It is reported that nearly 2000 traditional varieties were predominantly cultivated in Kerala. Demographic, social, policy and climatic forces have triggered fast disappearance of many of these landraces, leading to fast erosion of the diversity base. Presently, the extent of coverage of High Yielding Varieties (HYVs) of rice in the state is nearly 93%, which is dominated by a few varieties. The worry of substitution of diverse set of genetically variable crop land races by a few genetically uniform

modern varieties is widely expressed in literature (Brush, 1991). It has translated into the creation of gene banks around the world, *i.e.*, *ex situ* conservation (Plucknett *et al.*, 1987). However, there is a disadvantage that the genetic resources conserved *ex situ* are frozen at the evolutionary clock when they are collected (Jackson, 1995). This naturally underlines the importance of *in situ* conservation efforts.

This paper analyses the present status and trend in the cultivation of traditional varieties (TVs) and HYVs of rice in Kerala. The relative production merits of traditional vs. high yielding varieties and the societal behaviour towards conservation are also discussed based on data from an ecologically sensitive organic farming rice tract. The information may facilitate developing a suitable policy for *in situ* conservation of indigenous land races.

MATERIAL AND METHODS

This paper involves analysis of both primary and secondary data based on rice farming. The data on area, production and productivity of (HYVs) and (TVs) published by Directorate of Economics and

Statistics, Government of Kerala for the period from 1995 to 2011 was compiled and statistically analysed. The average annual growth rate and coefficient of variation was estimated.

The primary data was gathered from the identified respondents of the prominent rice growing areas of the state. The study area, *Pokkali* tract is spread over 5,500 hectares throughout the districts of Ernakulam, Thrissur and Alappuzha of Kerala in Southern India. *Pokkali* (pronounced *Pokkaalli*) is a unique saline tolerant rice variety that is cultivated in an organic way in the water-logged coastal regions of Kerala. One season of rice is followed by prawn farming thus facilitating nutrient recycling. No external chemical or organic inputs are applied. Thus, the organically-grown *Pokkali* is famed for its peculiar taste and high protein content and it has got the Geographical Indication (GI) registration for its uniqueness.

The data for the study was gathered through personal interview method using structured interview schedule. For this purpose, 37 farmers were randomly chosen and post-stratified based on the variety (High Yielding Variety /Traditional Variety) cultivated. This included farmers who have been cultivating traditional variety (*Pokkali*) and those are cultivating HYV (*Vytilla 6*) for the past 5- 10 years.

To quantify the contribution of technology (variety) and resource use efficiency in the HYV and TVs, Cobb-Douglas production function was fitted,

$$Y = aX_1^{b_1} \cdot X_2^{b_2} \cdot X_3^{b_3} e^{\mu}$$

where,

Y= output of rice (kg ha⁻¹)

X₁= seed rate (kg ha⁻¹)

X₂= labour (man days ha⁻¹)

X₃= variety as dummy variable (TV-0, HYV- 1)

i= Random disturbance term in conformity with the OLS assumptions

b_i= Slope parameter of regression function

a= Scale parameter

The social factors that influenced the farmer's decision to choose the variety were analyzed employing the probit model:

$$P_i = \frac{1}{1 + e^{-z_i}} \quad \text{where } P_i \text{ is the probability that the farmers use traditional varieties}$$

$$P_i = 1 - \frac{1}{1 + e^{-z_i}} \quad \text{where } P_i \text{ is the probability that the farmers use HYVs}$$

Taking logarithm on both sides,

$$\frac{\ln(P_i)}{1-P_i} = Z_i = a + \sum \hat{a}_i + X_i + e_i$$

Where X_i is the vector of independent variables and \hat{a}_i are the coefficients to be estimated. The independent variables were the age, education of the farmer and the area under rice cultivation. It was hypothesized that age and education have positive influence on the selection of traditional varieties while the area under rice farming is having negative influence.

RESULTS AND DISCUSSION

Rice production scenario in Kerala

Kerala state, where the staple food is rice, is producing only one-fifth of the domestic requirement. At the same time, area under rice cultivation and the production has been exhibiting a declining trend over the past several years (1995-2011). Table 1 detail the trend in the area, production and productivity of rice during this period. The average rate of decline in area during the period 1995-2011 is estimated at 4.84 per cent per annum. In 1995-96 the rice area was 4.71 lakh ha which had declined to 2.13 lakh ha in 2010-11. The production has come down from 9.53 lakh tonnes to 5.98 lakh tonnes during the same period. The rate of decline was to the tune of 3.68 per cent per annum.

The productivity of rice exhibits a positive growth trend at 1.48 per cent per annum which limits the external dependence to some extent. This increase in productivity is mainly attributed to the

coverage of High Yielding Varieties. Many high yielding/improved varieties are released by Kerala Agricultural University for the different rice ecosystems of Kerala. Most widely accepted varieties include *Uma*, *Jyothi*, *Jaya*, *Anaswara* and *MattaTriveni*. The production from HYVs was reported as 3.87 lakh tonnes in 1995-96, which increased to

4.98 lakh tonnes in 2010-11 at a growth rate of 1.59 per cent per annum. The increase in HYV coverage during the same period was 1.2 per cent per annum (1.64 lakh ha to 1.98 lakh ha) and the productivity improvement was to the tune of 0.39 per cent per annum *i.e.* from 2362tonnes per hectare to 2513 tonnes per hectare.

Table 1.Trend in rice production in Kerala (1995-2011)

Variety	Area	Production	Productivity
HYV	1.20**	1.59***	.39***
Traditional	-17.21***	-17.79***	-.70***
Total	-4.84***	-3.68***	1.48***
*** Significant at 1% level		** Significant at 5% level	

Source : Farm Guide (2012)

Thus, it is clear that the decline in area and production is mainly in the case of TVs. The very high rate of decline in area under cultivation is mainly observed in the case of TVs (-17.21%), which is correspondingly reflected in the output as well (-17.79%). Obviously, the productivity has also been declining from 1842 tonnes per hectare to 1645 tonnes per hectare. The traditional varieties of Kerala, which were location specific, thus, slowly disappeared causing erosion to the diversity base and rich traditional wealth. The varieties in this group are *Pokkali*, *Cheruvirippu*, *Chettivirippu*, *Orumundakkan*, *Thavalakkannan*, *Chitteni* and many others.

There are three major rice growing seasons in Kerala, Autumn[1st season (April/May to Sept / Oct)], Winter[2nd season (Sept/Oct to Dec/ Jan)] and Summer [3rd season (Dec/ Jan to March/ April)]. The TVs were mainly grown in winter season. During 1995-96, 56 per cent of TV coverage was in

winter season. The comparatively high straw yield (1:1grain: straw ratio in TVs and 2:1 in HYVs) in TVs was the major reason for the choice. The harvesting time in winter was favourable for drying and staking the straw for year round purpose. Consequent to the decline in the livestock population (from 33.99 lakh in 1996 to 17.40 lakh in 2007) the demand for straw also declined. This naturally might have triggered the replacement of traditional varieties with HYVs even in winter season. By 2010-11, coverage of TVs in winter season has come down to 13,101 ha. However, the rate of decline was lowest in winter (-14.9%) compared to autumn (-23.39%) and summer (-23.8%).

It is to be noted that the entire decline in rice area is in TV coverage during winter and summer seasons, whereas the HYV coverage is showing an increase over years, the rate of increase being highest during winter season. Thus, extend of spread of the HYV's is more prominent in this season.

Table 2. Season wise growth rate of rice area in Kerala (1995-2011)

Variety \ Season	Autumn	Summer	Winter	Overall
HYV	-0.21	2.65*	1.32	1.20**
Traditional	-23.39***	-14.9***	-23.8***	-17.21***
* 10% level of significance ** 5% level of significance *** 1 % level of significance				

Source : Farm Guide (2012)

Irrigation is a critical input in HYV cultivation, as it is a pre-condition for fertilizer use, especially during winter and summer. Of the total rice area, 63.31 per cent is irrigated (2004-05). HYVs are mainly grown under irrigated condition, occupying 88 per cent of total irrigated rice cultivation. Sixty-five per cent of total rice production of Kerala is also from

irrigated area and the bulk of it is from HYVs (90.4%). Comparing the productivity between HYVs and traditional varieties grown under irrigated and rainfed conditions, highest productivity was seen for HYVs under irrigation (3845 kg ha⁻¹) and the lowest productivity for traditional varieties grown under rainfed condition (1522 kg ha⁻¹), which is expected (Table 3).

Table 3. Season wise area, production and productivity of rice in Kerala (2004-05)

Season \ Variety	HYV		TV	
	Irrigated	Rainfed	Irrigated	Rainfed
Area (in ha)				
Autumn	20798	58210	893	6897
Winter	105514	14059	20787	12476
Summer	35184	4717	425	1
Total	161496	76986	22105	19374
Production (in tonnes)				
Autumn	522337	178353	1046	10088
Winter	250535	22911	39759	22324
Summer	88794	350	607	1
Total	391666	201614	41412	32413
Productivity (kg ha⁻¹)				
Autumn	3830	3537	1783	2226
Winter	3614	3447	2911	2724
Summer	3845	3319	2866	1522

Source : Farm Guide (2012)

Difference in area, production and productivity can be seen for the three seasons in the case of HYVs and TVs under irrigated and non-irrigated conditions. For HYVs grown non irrigated situation, crop productivity is more in summer season. Under rainfed conditions HYVs were grown extensively in autumn season compared to winter and summer. The production (178,353 tones) and productivity (3537 kg ha⁻¹) is also highest in this season. Hence, it can be concluded that for HYVs, highest productivity can be observed in summer season if it is irrigated and under rainfed condition, productivity is higher in autumn season.

In the case of traditional varieties highest area (20,787 ha), production (39,759 tonnes) and productivity (2911 kg ha⁻¹) was observed in winter season, under irrigated condition. However, the area under TVs during winter season has been reducing at the rate of -14.9 per cent. The situation was the same under rainfed conditions too *i.e.*, the highest area, production and productivity was observed in winter season. The productivity of TVs was observed to be highest in winter season, both under irrigated and rainfed conditions. At the same time, the extend of coverage of the varieties shows a decline in this season, over the years.

Thus, it can be concluded that the decline in rice area is mainly in the cultivation of TVs. Even when the threat of water scarcity and climate change impacts are predicted, the spread of HYVs are fast. The decline of area under traditional varieties in winter season is a major matter of concern, as it was the major season during which traditional varieties were grown and the performance was best.

The Varietal effect

The improved varieties released by KAU from Rice Research Station, Vytilla, which is the station for rice research in the *Pokkali* tracts of Kerala are *Vytilla 1*, *Vytilla 2*, *Vytilla3*, *Vytilla 4*, *Vytilla 5*, *Vytilla 6*, *Vytilla 7* and *Vytilla 8* of which *Vytilla 6* is the

most popular among the respondent farmers. The traditional variety *Pokkali* was grown by 23 farmers.

The management of *Pokkali* cultivation follows organic methods, mainly due to geographical peculiarities. The land is prepared by strengthening bunds and making mounds of 1m height and 0.5m base on which seeds are sown. The seed rate recommended for *Vytilla* varieties are 100 kg ha⁻¹ and for local variety is 80-100 kg ha⁻¹. The seeds are sprouted on the mounts and when the seedlings reach the height of 40-45 cm (in 30-35 days), the mounds are cut into pieces with a few seedlings, which are uniformly spread in the field. Later the gap filling is done.

Generally, chemical fertilizers are not used in *Pokkali* cultivation. Organic manure content in these soils is reported to be high due to shrimp farming and crop residue of the previous crop. Hence, they do not apply any organic manure. Weeding is the only intercultural operation performed. Harvesting is done by cutting only the panicles leaving the rest of the biomass for decaying. Thus, there is no difference in management practices between these two groups. The socio-economic status of the rice farmers showed that more than 50 per cent of the farmers are above 50 years of age. More than three-fourth of the respondents had schooling less than twelve years. The average family size is 4- 5 members per family.

The production response of *Vytilla* and *Pokkali* varieties was examined with the help of Cobb-Douglas Production function fitted to the cross sectional farm level data collected from the farmers. The production function was estimated using Ordinary Least Square Technique. The estimates are given in the Table 4. The result of the analysis pooling the observation confirms the hypothesis that HYVs has a significant positive influence on the crop yield. The coefficient estimates the increase in yield at 1.38 per cent higher due to the adoption of HYVs compared to traditional varieties. This naturally acts as a strong

determinant for the adoption of HYVs. The possibility of increasing the yield through increasing the seed rate of traditional varieties is revealed through the results as the coefficient is positive and significant at 0.46 per cent. Generally the farm saved seeds are used by farmers cultivating traditional varieties. Department of Agriculture (DoA) supplies the seeds

of HYVs which are fully subsidized. This support is not extended to farmers who use farm saved seeds in the case of TVs. It is important that the subsidy be extended to the TVs also, so that the farmers have the economic incentive to conserve the traditional varieties, and perhaps increase the seed rate so that they realize higher production.

Table 4. Estimated production function for rice cultivation in Pokkali

S. No.	Explanatory variable	Regression coefficients		
		Vytilla variety	Pokkali variety	Pooled
1	Intercept A	11.52***	4.34***	7.244***
2	Seed rate X1	0.31	0.46***	0.35
3	Labour days X2	-1.36	-0.13	-0.45**
4	Variety (dummy) X3	-	-	1.38***
	Coefficient of determination (R ²)	0.51	0.65	0.78

*** Significant at 1%; ** Significant at 5%; * Significant at 10%

Relative risk in rice farming

Though HYVs are known for higher yield realization, they are generally sensitive to management practices and weather, and the risk is considered to be high. The results of the estimates of coefficient of variation in these cases are furnished in Table 5. The variability in production was found to be higher for HYVs in both the cases for primary and secondary data. For HYVs it was found to be

7.08 per cent and 6.12 per cent for local varieties when Kerala state as a whole was considered. The result was found to be comparable in the case for *Vytilla* variety which was estimated as 45.93 per cent and for *Pokkali* variety was 33.19 per cent, thus confirming our hypothesis. Hence, this low risk level may be one of the reasons that prompt at least a few farmers to continue the use of TVs, despite the better yield realization and policy support for HYVs.

Table 5. Coefficient of variation in production of HYVs and TVs

Variety	Secondary data		Primary data	
	TV	HYV	<i>Pokkali</i>	<i>Vytilla 6</i>
Coefficient of variation (%)	6.12	7.08	33.19	45.93

Choice of variety

In this background, an analysis was done to segregate some of the factors that influenced the decision making regarding the choice of varieties. It was hypothesized that the age and education level had a positive impact on preference towards TVs.

The area under farming was expected to have negative influence. The results are furnished in the Table 6. As expected the area under rice cultivation was proved to have a significant impact on the decision making regarding the choice of variety. As the farming goes commercial (with high marketable

surplus) the tendency is to go for HYVs. At lower level, subsistence farming, where area under farming is small, the marketable surplus is low. Thus, the small and marginal farmers may prefer low risk

strategies to ensure the farm income, through choosing the TVs. Thus, the coverage of the *Pokkali* variety is restricted to only small/marginal farms. Further, the TV *Pokkali* is preferred for its special culinary properties, taste and qualities.

Table 6. Estimated logit regression coefficients of factors influencing the choice of traditional variety

S.No.	Variable (Xi)	Coefficient (β)	Standard Error
1	Constant	-1.180	1.643
2	Age (years)	.145	0.389
3	Education	.703	0.874
4	Rice area (in ha)	-.579*	0.433

*Significant at 10%

CONCLUSION

The rice cultivation in Kerala is facing serious challenges. The shrinking area under rice farming is attributed to demographic, social, economical and political factors. The general decline in area under cultivation, wiped out the traditional varieties at a faster pace due to obvious reasons of policy support and relative economics in favour of HYVs. The situation is no different in *Pokkali* area as well. The better yield realization and policy factors favour the spread of *Vytilla* varieties (HYVs) despite higher levels of risk. The cultivation of local varieties is slowly getting confined to small and marginal rice holdings, for subsistence income and domestic consumption. The policy intervention at this juncture warrants focused efforts for conservation of the traditional varieties. All the supports extended to HYVs are to be extended to TVs (farm saved seeds) and there should be institutional arrangements to market the organically grown and locally preferred varieties to be procured at higher price to compensate for the difference in yield. The incentive for conserving the traditional variety can be considered as the policy instrument.

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MARKETING EFFICIENCY AND MARKET COMPETITIVENESS OF FARMER PRODUCER COMPANIES (FPCs) - A CASE OF TELANGANA AND KARNATAKA STATES

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ABSTRACT

India is predominantly dominated by small and marginal farmers and the growing trend of sub-division and fragmentation of landholdings continues to fuel the proliferation of small and marginal farmers. The concept of Farmer Producer Companies (FPCs) is a way forward to address several problems of small and marginal farmers. Two farmer producer companies (FPCs) from Karnataka state and three FPCs from Telangana state were taken for the study. Marketing costs, marketing margins, marketing efficiency and price spread were analyzed from the major two marketing channels viz., FPC channel and Farmers channel. It was observed that marketing efficiency and producer share in consumer rupee was higher in FPC channel due to reduction in transaction costs. Moreover, FPC farmers received better prices compared to MSP and modal prices in both Telangana and Karnataka states for the year 2014-15 compared to 2015-16, which indicates farmers forming as producer companies have added advantages in terms of increase in income level and supply chain efficiency .

INTRODUCTION

A majority of the world's poor belong to agricultural based rural households. Small and marginal farmers in India constitute 85 per cent of the operated holdings and are cultivating 44.5 per cent of operated area. While indebtedness is often cited as the immediate reason for distress (Reserve Bank of India, 2006; Satish, 2007) and deeper issues were related to lower scale of operation, lack of information, poor communication linkages with the wider markets and consequent exploitation by intermediaries in procuring inputs and marketing fresh produce, access to and cost of credit (Dev, 2005) and in isolated cases aggressive loan recovery practices (Sriram, 2008).

A variety of approaches had emerged to resolve the problems faced by small and marginal farmers like formation of co-operative credit societies, private participation promoted through contract farming and encouraging different forms of community organizations like Self Help Groups (SHGs), Common Interest Groups (CIGs), Farmers clubs, New Generation Co-operatives (NGC) and producer company (PC) the newly emerged concept. It is new

legal entity of the producers of any kind, viz., agricultural produce, forest produce, artisan products, and any other local produce where the members are primary producers and company to be registered as per companies Act of 1956. Currently Farmer Producer Companies (FPCs) work in dynamic, ever evolving market economies and promote entrepreneurial spirit. A majority FPCs being operated in India were mainly driven to improve the efficiency of supply chain and thereby reduce marketing costs. Against this background the study was undertaken with the following objectives. The data collected pertains to agricultural year 2015-16. The objectives of the study are to analyse the marketing costs and marketing margins incurred by FPCs, to analyze the marketing efficiency and price spread of FPCs and to estimate the market competitiveness of the FPCs.

Producer Organisations

Producer organizations are formal rural organizations whose members organized themselves with the objective of improving farm income through improved production, marketing, and local processing activities (Rondot and Collion, 2000). The main goal

of the producer organisation was to provide services that support producers in their farming activities, including the marketing of the farm products. (Bijman and Wollni, 2008). Producer company as a new answer in not only rectifying the imperfect experiences of cooperatives but also strengthening the leverage of small and marginal farmers through collective means, and integrating their livelihoods into remunerative markets. (Shylendra, 2009)

Market Competitiveness

The competitiveness rests on cost reduction strategies which can be achieved through economies of scale, either in terms of input provision, technical assistance or commercial logistic through farmer's organization (Estelle and Danies, 2005). The Farmer Producer Organizations (FPO) were best structures in eliminating the various transaction costs of marketing in the economy using the tools of Transaction Cost Economics (TCE) (Varun Prasad,

2013). Farmer organisations have the potential to improve services and reduce transaction costs, but issues such as downward accountability, poor management need to be addressed (Robert and Peter, 2014)

MATERIAL AND METHODS

From the total list of farmers' producer companies available in Small Farmers Agribusiness Consortium website (SFAC), the producer companies existing in Karnataka and Telangana states were taken and classified based on various promoters involved in it. Out of total eight and nine FPCs in Karnataka and Telangana States, purposively three FPCs from Mahabubnagar district of Telangana and two from Bijapur district of Karnataka states were selected since these FPCs were promoted by the same promoter. The FPCs under study were growing one single crop *i.e.* redgram. A set of pre-tested schedules were used to collect pertinent data from farmer shareholders.

District	Name of the FPCs
Bijapur(Karnataka)	1. Kalkeri Farmers services producer company(KFSPC) 2. Jalwad Farmers services producer company (JFSPC)
Mahabubnagar (Telangana)	1. Angadiraichur Farmers services producer company (AFSPC) 2. Hasnabad Farmers services producer company (HFSPC) 3. Kodangal Farmers services producer company (KFSPC)

Marketing Cost

The actual expenses incurred (handling charges, assembling charges, transport and storage costs, expenses incurred for secondary services) in bringing the produce from producers to consumers constitute marketing costs.

The Marketing cost was estimated with the help of following formula

$$C = C_F + C_{m1} + C_{m2} + C_{m3} + \dots + C_{mi} \dots 1$$

Where,

C = Total cost of marketing (Rs q⁻¹)

C_F = Cost paid by the producer (Rs q⁻¹)

C_{mi} = Cost incurred by the ith middle in the process of marketing (Rs q⁻¹)

Marketing Margin

Marketing margins are costs of equipment, transport, labour, capital, risk, and management. It is the summation of share earned by various market intermediaries for moving the produce from producer to consumer in a marketing channel.

Marketing Efficiency

The Marketing efficiency of different Marketing channels considered under the study was estimated by Acharya and Agarwal's Approach

$$ME = FP / (MC + MM) \text{ ————— } 2$$

Where,

ME = Index of marketing efficiency

FP = Price received by the farmer

MC = Total marketing costs

MM = Net marketing margins

Producers Share in Consumers' Rupee

It is the price received by the producer expressed as percentage of the retail price (price paid by the consumer). If Pr is the retail price and Pf is the producers' price, then the producers' share in consumers' rupee (Ps) may be worked out as follows;

$$Ps = (Pf / Pr) * 100 \text{ ————— } 3$$

Where,

Ps = Producers' share in consumers' rupee

Pf = Price received by the producer

Pr = Price paid by the consumer

RESULTS AND DISCUSSION

i) Marketing Channels

The following marketing channels were being operated majorly in the study area in marketing of redgram.

- (i). Farmers – Commission Agent – Trader – Miller – Wholesaler – Retailer – Consumer
- (ii). Farmers – Farmer Producer Company - Trader - Miller – Wholesaler – Retailer – Consumer

ii) Analysis of Marketing costs and Marketing Margins

a) Marketing Costs

The costs involved in marketing of redgram in channel I and Channel II were analyzed and results are presented in table 1.

Table 1. Analysis of marketing costs under different channels in the marketing of red gram (Rs q⁻¹)

S. No	Functionaries	Marketing Costs (Rs q ⁻¹)	
		Traditional Marketing (Channel I)	FPC (Channel II)
1	Producer – Farmer	240 (8.78)	25 (1.1)
2	Commission Agent	102 (3.73)	0
3	Farmer Producer Company	0	38 (1.54)
4	Trader	190 (6.95)	190 (7.71)
5	Processor	1805 (66.06)	1805 (73.28)
6	Wholesaler	185 (6.77)	185 (7.51)
7	Retailer	210 (7.68)	210 (8.53)
8	Total	2,732 (100)	2,463 (100)

(Figures in parentheses indicate the percentages to total costs incurred)

It is observed from Table1 that total marketing cost incurred for redgram in Channel I was Rs. 2732/- per quintal and in channel II was Rs. 2463/- per quintal. It implied that farmers who disposed the produce on their own incurred relatively more costs (Rs.269 q⁻¹) compared to the FPC shareholder farmers. Within the channel, marketing

cost incurred by the processor was more compared to other market functionaries followed by retailer, trader, wholesalers and commission agents.

b) Marketing margins

The marketing margins incurred in marketing of redgram in Channel I and Channel II were analyzed and results are presented in Table 2.

Table 2. Analysis of marketing margins under different channels in the marketing of redgram (Rs Q⁻¹)

S. No	Functionaries	Marketing Margin (Rs q ⁻¹)	
		Traditional Marketing (Channel I)	FPC (Channel II)
1	Producer – Farmer	0	0
2	Commission Agent	138 (14.55)	0
3	Farmer Producer Company	0	105(11.47)
4	Trader	110 (11.6)	110 (12.02)
5	Processor	395(41.66)	395(43.16)
6	Wholesaler	115 (12.13)	115(12.56)
7	Retailer	190 (20.04)	190(20.76)
8	Total	948(100)	915(100)

(Figures in parentheses indicate the percentages to total margins incurred)

It is inferred from Table 2 that the margins earned in marketing of redgram through Channel II (Rs.915/-) was less than Channel I (Rs.948/-), which implied that the when the farmer was selling his produce to FPC, marketing margins earned by market functionaries is minimized (3%). Compared to total marketing margins, margins earned by processors, traders, wholesalers and retailers were more in channel II and channel I.

iii) Analysis of Marketing Efficiency and Price Spread

a) Marketing Efficiency

Marketing efficiency is the measure of availability of information to all the participants in a market that provides maximum opportunities to buyers and sellers to effect transaction with minimum transaction costs. The results of marketing efficiency are presented in Table 3.

Table 3. Indices of marketing efficiency in the selected marketing channels

S. No	Particulars	Traditional marketing (Channel I)	Farmer producer company (Channel II)	Per cent difference between Channel I and Channel II
1	Price received by the farmer (Rs)	5660	5875	3.65
2	Marketing costs + Marketing margins (MC+MM) (Rs)	3680	3378	-8.95
3	Index of Marketing Efficiency (MME)	1.53	1.73	11.56

It is implied from Table 3 that due to better price received by farmer and low marketing cost and marketing margins, Channel II was more efficient than Channel I. Despite taking all the risks in arranging his produce to sell directly, farmer is exploited by market intermediaries at some stages.

b) Price Spread Analysis

The price spreads under two prominent channels *i.e.*, Channel I (Farmer Marketing) and Channel II (FPC Marketing) in the marketing of redgram has been presented in Table 4.

Table 4. Price spread under different marketing channels in the marketing of redgram (Rs q⁻¹)

S.No	Items	Farmer Marketing (Channel I)	FPC(Channel II)
1	Producer's net price	5660 (62.19)	5875 (64.56)
2	Producer's market price	5900 (64.83)	5900 (64.83)
3	Commission agent's selling price	5900 (64.83)	0
4	Farmer producer company's selling price	0	5900 (64.83)
5	Trader's selling price	6200 (68.13)	6200 (68.13)
6	Processor's selling price	8400 (92.30)	8400 (92.30)
7	Wholesaler's selling price	8700 (95.60)	8700 (95.60)
8	Retailer's selling price	9100(100)	9100(100)
9	Price spread	3440 (37.80)	3225 (35.44)
10	Producer's share in consumer's rupee	62.198	64.56

Figures in parentheses indicate the percentages to the retail price (consumer's price)

Since price spread is directly proportional to the number of intermediaries involved in the marketing of a produce, the channel-II where producer was directly approaching the market through FPC,

was found to have marginally higher producer share (2.36%) in consumer price compared to farmer marketing channel.

iii) Market Competitiveness

Marketing competitiveness of FPC over other farmers was analyzed taking into consideration Minimum support price (MSP), FPC selling price and open market price for redgram prevailing for the year 2013-14 and

2014-15 in Telangana and Karnataka states and results are presented in the tables shown below. The modal prices prevailing in Tandur market of Telangana and Gulbarga market of Karnataka for redgram were taken as they are major markets for redgram in respective states.

Table 5. Red gram prices in Telangana and Karnataka (2014-15)

Month/ Market	MSP (Rs q ⁻¹)	FPC selling price (Rs q ⁻¹)	Modal price (Rs q ⁻¹)
Red gram prices in Telangana (2014-15)			
December	4350	5472	4997.73
January	4350	5323	4847.98
February	4350	5172	5854.41
Average	4350	5323.33	5233.37
Red gram prices in Karnataka (2014-15)			
December	4350	5470.1	4874.64
January	4350	5322.5	5151.70
February	4350	5172.2	5831.29
Average	4350	5321.6	5287.21

It is observed from the Table 5 that FPCs selling price for the year 2014-15 in the state of Telangana and Karnataka were higher than that of both MSP (Rs.4350/Qn) and average modal price. Though the market committee ensures care to grade the produce brought for sale by the farmers, yet the system has some limitations, which does not reflect truly on the quality of the produce. Such limitations are overcome in the FPCs in which the farmers were rewarded with better price for their produce. The year 2014-15 incidentally happens to be a bright year for

pulses in general. The price received by the farmers is quite encouraging. But it was not the same story in the year 2013-14, during which period the redgram prices were more often less than the MSP. This could be observed from the Table 6 that the price of redgram in open market was less compared to MSP. This problem was fixed to certain extent by the involvement of FPCs through SFAC, which procured the members produce at MSP. This is also could be put forth on the positive side because the price received in the open market was very discouraging.

Table 6. Red gram prices in Telangana and Karnataka (2013-14)

Month/ Market	MSP (Rs q ⁻¹)	FPC selling price (Rs q ⁻¹)	Modal price (Rs q ⁻¹)
Red gram prices in Telangana (2013-14)			
December	4300	4300	3784.37
January	4300	4300	4167.30
February	4300	4300	3990.85
Average	4300	4300	3979.84
Red gram prices in Karnataka (2013-14)			
December	4300	4300	3894.28
January	4300	4300	4030.38
February	4300	4300	4000.85
Average	4300	4300	3975.17

CONCLUSIONS

The disadvantages they face are high unit transaction costs in almost all non-labour transactions. The study undertaken on FPCs revealed that they not only help farmers buy or sell better due to scale benefits but also lowers transaction cost for sellers and buyers besides providing technical help in production and creating social capital. As encouraging the formation of FPC has many advantages, state governments, NGOs and other stake holders involved for the benefit of farming community should play an active role in motivating farmers to organize themselves as FPC and render all sort of technical, financial, marketing, capacity building and mentoring assistance for their sustenance in long run.

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KNOWLEDGE MAPPING ON RICE (*Oryza sativa* L.) PRODUCTION TECHNOLOGIES BY THE FARMERS OF KARIMNAGAR DISTRICT IN TELANGANA STATE

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ABSTRACT

The present paper highlights the knowledge levels of farmers on rice production technologies in Karimnagar district of Telangana State (Formerly Andhra Pradesh). *Ex-post facto* research design was adopted for study. Total ninety (90) farmers were selected for study of rice crop knowledge mapping (2013-14). Out of 90 farmers, 60 farmers are KVK adopted farmers and 30 farmers were KVK non adopted farmers. High level of knowledge of rice production technologies is observed among the KVK Jammikunta adopted farmers in all the rice production technologies compared to the non adopted farmers.

INTRODUCTION

Knowledge is key ingredient in application of any technology. It reflects an array of information possessed by an individual. It plays a pivotal role in understanding the intricacies involved in any given phenomena. The *Krishi Vigyan Kendra* (KVK)s are rendering a great help to the farmers in increasing the level of knowledge on various crops, these institutions conducting different programmes to enlighten the farmers on various crop production technologies. Rice is one of the main crops of Karimnagar district and the present paper focuses on knowledge mapping of the farmers on rice production technologies in Karimnagar district.

MATERIAL AND METHODS

Ex-post facto research design combined with exploratory type of research design was used, as the selected phenomena have already occurred and the researcher had no control over the same. The KVK Jammikunta of Telangana State (Formerly Andhra Pradesh) along with its 15 adopted villages was selected for the study (2013-14). A sample of 60 rice growing farmers who are adopting the KVK technologies and 30 rice farmers who are not covered under KVK production technologies were selected from the adopted villages. A schedule was developed

with 29 technologies to assess the knowledge levels of the rice growing farmers which is measured on 2 point continuum *i.e.* yes and no, with the scores of 2,1, respectively. Accordingly, the respondents were grouped on the basis of frequency and percentage.

RESULTS AND DISCUSSION

It is observed from Table 1 that majority (43.34%) of the KVK adopted rice farmers had high level of knowledge followed by medium (31.66%) and low (25.00%) whereas, majority (40.00%) of the KVK non adopted rice farmers had medium level of knowledge followed by low (33.34%) and high (26.66%). These results are in conformity with the results of Balamatti (1994), Bhat (1993) and Rao *et al.* (2012).

Comparison between KVK adopted and non adopted rice farmers in terms of level of knowledge of rice production technologies

It is evident from the Table 2 that calculated 'Z' Value (3.53) is greater than table 'Z' value at 0.01 level of probability. Hence, the null hypothesis was rejected and hence it could be concluded that there exists a significant difference between mean scores of KVK adopted and non adopted farmers.

Table 1. Distribution of respondents according to their level of knowledge of rice production technologies

Category	KVK adopted rice farmers (N=60)			KVK non adopted rice farmers (N=30)		
	Low (29-38)	Medium (39-48)	High (49-58)	Low (29-38)	Medium (39-48)	High (49-58)
Frequency	15	19	26	10	12	8
Percentage	25.00	31.66	43.34	33.34	40.00	26.66

Table 2. Comparison between KVK adopted and non adopted rice farmers in terms of level of knowledge of rice production technologies

S. No.	Respondent category	Size of the sample(N)	Mean	S.D.	'Z' value
1.	KVK adopted farmers	60	56.58	3.02	3.53*
2.	Non adopted farmers	30	34.73	3.16	

*Significant at 0.01 level of probability

Table 3. Item wise analysis of adopted farmers on level of knowledge of rice production technologies

N=60

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
1	Soil samples are collected up to 15-20 cm depth in 'V' shape for soil testing	54	90.0	06	10.0	114	1.90	V
2	Soil test based fertilizer application is economical	53	88.3	07	11.7	113	1.88	VI
3	Growing of green manure crop preceding to rice and incorporation into the soil improves the soil fertility	56	93.3	04	6.7	116	1.93	III
4	Seed treatment with fungicide reduces the disease incidence in the initial stages of plant growth	52	86.7	08	13.3	112	1.86	VII
5	Spraying of herbicide cyhalofop butyl 10% solution @ 2 ml lt ⁻¹ of water reduces the weeds of <i>Echinochloa</i> in nursery	50	83.3	10	16.7	110	1.83	VIII

KNOWLEDGE MAPPING OF RICE PRODUCTION TECHNOLOGIES BY FARMERS

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
6	Application of 1 kg carbofuran granules in rice nursery before one week of transplantation reduces stem borer and gall midge incidence in early stages of plant growth	56	93.3	04	6.7	116	1.93	III
7	Transplantation of lesser seedlings(2-3) per hill and shallow transplantation facilitates more tillers and leads to higher yields	50	83.3	10	16.7	110	1.83	VIII
8	Application of recommended complex fertilizers at basal and straight fertilizers in split doses reduces the pest and disease incidence	50	83.3	10	16.7	110	1.83	VIII
9	Creation of alley ways help to control BPH	56	93.3	04	6.7	116	1.93	III
10	Weeds can be effectively controlled by using recommended herbicides at 3-5 days after transplanting by keeping a thin film of water in the field	58	96.7	2	3.3	118	1.96	II
11	Mid season drainage is important for obtaining higher yields	52	86.7	08	13.3	112	1.86	VII
12	Timely management of zinc deficiency with foliar spray increases the yields	54	90.0	06	10.0	114	1.90	V
13	Last dose of recommended fertilizers applied before panicle initiation reduces pest and diseases	50	83.3	10	16.7	110	1.83	VIII
14	Application of urea with neem cake or neem oil reduces the nitrogen loss	48	80.0	12	20.0	108	1.80	IX
15	Harvesting of rice need to be done close to the ground level to prevent pest incidence	56	93.3	04	6.7	116	1.93	III
16	Aerobic rice does not require wet land preparation and thus reduces the time for land preparation	30	50.0	30	50.0	90	1.50	XII
17	Direct seeding in rice with drumseeder reduces labour requirement, seed rate and facilitates timely sowing	53	88.3	07	11.7	113	1.88	VI

Contd..

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
18	Direct seeding in rice with drumseeder reduces the crop period by 7-10 days and will also avoid one irrigation	53	88.3	07	11.7	113	1.88	VI
19	direct seeding in rice with drumseeder yields at par with normal transplantation	53	88.3	07	11.7	113	1.88	VI
20	In SRI high yields will be obtained with low cost of cultivation and with low water consumption	50	83.3	10	16.7	110	1.83	VIII
21	Post emergence herbicide cyalofop butyl @ 400 ml acre ⁻¹ and ethoxy sulfuron @ 50 gm acre ⁻¹ spraying at 2-3 leaf stage of weeds will effectively control all the weeds	45	75.0	15	25.0	105	1.75	X
22	Post emergence herbicide bispyribac sodium @ 120 ml acre ⁻¹ effectively controls both the monocots and broad leaved weeds	45	75.0	15	25.0	105	1.75	X
23	WGL -32100(Warangal Sannalu), a fine grain variety has good cooking quality, will come to harvest 15 days early than BPT 5204 and gives higher yield than BPT 5204	55	91.7	05	8.3	115	1.91	IV
24	NLR 34449, a fine grain variety has good cooking quality and blast tolerance and gives higher yield than BPT 5204	50	83.3	10	16.7	110	1.83	VIII
25	Low seed rate per acre with proper management practices will also give higher yields and result in low cost of cultivation	50	83.3	10	16.7	110	1.83	VIII
26	Grain discolouration (panicle mite) will be effectively controlled with prophylactic spray with profenophos @ 400 ml and propiconazole @ 200 ml acre ⁻¹ before panicle emergence.	50	83.3	10	16.7	110	1.83	VIII
27	Hybrid seed production in rice gives higher net returns compared to normal rice cultivation	60	100.0	0	0.0	120	2.00	I
28	Stem borer will be effectively controlled through mass trapping with pheromone traps	40	66.7	20	33.3	100	1.66	XI
29	Seed production gives higher net returns compared to normal rice cultivation	60	100.0	0	0.0	120	2.00	I

Table 4. Item wise analysis of non adopted farmers on level of knowledge of rice production technologies

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
		1	Soil samples are collected up to 15-20 cm depth in 'V' shape for soil testing	15	50.0			
2	Soil test based fertilizer application is economical	15	50.0	15	50.0	45	1.50	V
3	Growing of green manure crop preceding to rice and incorporate into the soil improves the soil fertility	22	73.3	08	26.7	52	1.73	II
4	Seed treatment with fungicide reduces the disease incidence in the initial stages of plant growth	18	60.0	12	40.0	48	1.60	IV
5	Spraying of herbicide cyhalofop butyl 10% solution @ 2 ml lt ⁻¹ of water reduces the weeds of echinocloa in nursery	15	50.0	15	50.0	45	1.50	V
6	Application of 1 kg carbofuran granules in rice nursery before one week of transplantation reduces stem borer and gall midge incidence in early stages of plant growth	15	50.0	15	50.0	45	1.50	V
7	Transplantation of lesser seedlings(2-3) per hill and shallow transplantation facilitates more tillers and leads to higher yields	18	60.0	12	40.0	48	1.60	IV
8	Application of recommended complex fertilizers at basal and straight fertilizers in split doses reduces the pest and disease incidence	20	66.7	10	33.3	50	1.66	III
9	Creation of alley ways help to control BPH	20	66.7	10	33.3	50	1.66	III
10	Weeds can be effectively controlled by using recommended herbicides at 3-5 days after transplanting by keeping a thin film of water in the field	20	66.7	10	33.3	50	1.66	III
11	Mid season drainage is important for obtaining higher yields	20	66.7	10	33.3	50	1.66	III

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
12	Timely management of zinc deficiency with foliar spray increases the yields	20	66.7	10	33.3	50	1.66	III
13	Last dose of recommended fertilizers applied before panicle initiation reduces pest and diseases	18	60.0	12	40.0	48	1.60	IV
14	Application of urea with neem cake or neem oil reduces the nitrogen loss	15	50.0	15	50.0	45	1.50	V
15	Harvesting of rice need to be done close to the ground level to prevent pest incidence	20	66.7	10	33.3	50	1.66	III
16	Aerobic rice does not require wet land preparation and thus reduces the time for land preparation	10	33.4	20	66.6	40	1.33	VI
17	Direct seeding in rice with drumseeder reduces labour requirement, seed rate and facilitates timely sowing	10	33.4	20	66.6	40	1.33	VI
18	Direct seeding in rice with drumseeder reduces the crop period by 7-10 days and will also avoid one irrigation	10	33.4	20	66.6	40	1.33	VI
19	Direct seeding in rice with drumseeder yields at par with normal transplantation	10	33.4	20	66.6	40	1.33	VI
20	In SRI, high yields will be obtained with less cost of cultivation and less water consumption	10	33.4	20	66.6	40	1.33	VI
21	Post emergence herbicide cyalofop butyl @ 400 ml acre ⁻¹ and ethoxy sulfuron @ 50 gm acre ⁻¹ spraying at 2-3 leaf stage of weeds will effectively control all the weeds	15	50.0	15	50.0	45	1.50	V
22	Post emergence herbicide bispyribac sodium @ 120 ml acre ⁻¹ effectively controls both the monocots and broad leaved weeds	15	50.0	15	50.0	45	1.50	V
23	WGL -32100(Warangal Sannalu) a fine grain variety has good cooking quality will come to harvest 15 days lesser and gives higher yield than BPT 5204	20	66.7	10	33.3	50	1.66	III

KNOWLEDGE MAPPING OF RICE PRODUCTION TECHNOLOGIES BY FARMERS

S. No.	Rice production technologies	Level of knowledge				Total score	Mean score	Rank
		Yes		No				
		F	%	F	%			
24	NLR 34449 a fine grain variety has good cooking quality will have blast tolerance and gives higher yield than BPT 5204	20	66.7	10	33.3	50	1.66	III
25	Lesser seed rate per acre with proper management practices will also give higher yields with lesser cost of cultivation	20	66.7	10	33.3	50	1.66	III
26	Grain discolouration (panicle mite) will effectively controlled as prophylactic spray with profenophos @ 400 ml and propiconazole @ 200 ml acre ⁻¹ before panicle emergence	15	50.0	15	50.0	45	1.50	V
27	Hybrid seed production in rice gives higher net returns compared to normal rice cultivation	25	83.3	5	16.7	55	1.83	I
28	Stem borer will be effectively controlled through mass trapping with pheromone traps	15	50.0	15	50.0	45	1.50	V
29	Seed production in rice gives higher net returns compared to normal rice cultivation	25	83.3	5	16.7	45	1.83	I

Table 3 indicates the item analysis of the KVK adopted farmers in rice crop on level of knowledge possessed by them on rice technologies. It can be noted from Table 3 that ranks were assigned to all technologies based on the total score obtained on each technology. The technologies on which the respondents had high level of knowledge are hybrid rice and varietal seed production ranked 1st followed by weed management with recommended herbicides(2nd), green manuring to improve the soil fertility, application of carbofuran granules in nursery, creation of alley ways to control BPH (3rd rank), WGL 32100 a fine grain variety gives higher yield than BPT 5204 (4th), method of soil sample collection and timely management of zinc deficiency with foliar spray increases the yields (5th), soil test based fertilizer application, direct seeding reduces seed

rate, labour requirement and crop period with lesser cost of cultivation(6th), seed treatment with fungicide reduces the disease incidence in the initial stages of plant growth and mid season drainage is important for obtaining higher yields(7th), spraying of herbicide cyhalofop butyl 10% solution @ 2 ml lt⁻¹ of water reduces the weeds of echinocloa in nursery, transplantation of lesser seedlings(2-3) per hill and shallow transplantation facilitates more tillers leads to higher yields, application of complex fertilizers at basal and straight fertilizers in split up with recommended doses reduces the pest and disease incidence, last dose of fertilizers applied before panicle initiation reduces pest and diseases, in SRI higher yields will be obtained with lesser cost of cultivation and with lesser water, NLR-34449 a fine grain variety has good cooking quality will have blast

tolerance and gives higher yield than BPT 5204, lesser seed rate per acre with proper management practices will also give higher yields with lesser cost of cultivation and grain discoloration (Panicle mite) will effectively controlled as prophylactic spray with profenophos @ 400 ml and propiconazole @ 200 ml acre⁻¹ before panicle emergence (8th), application of urea with neem cake or neem oil reduces the nitrogen loss (9th), post emergence herbicide cyalofop butyl @ 400 ml acre⁻¹ and ethoxy sulfuron @ 50 gm acre⁻¹ spraying at 2-3 leaf stage of weeds will effectively control all the weeds, post emergence herbicide bispyribac sodium @ 120 ml acre⁻¹ will effectively controls both the monocots and broad leaved weeds(10th), stem borer will be effectively controlled through mass trapping with pheromone traps (11th) and aerobic rice does not require wet land preparation reduces the time for land preparation with lesser labour and lesser seed rate (12th), respectively. The KVK adopted farmers had lowest level of knowledge on aerobic rice and mass trapping with pheromone traps will effectively controls stem borer.

In case of non adopted KVK farmers, the practices such as hybrid rice and varietal seed production ranked 1st followed by green manuring to improves the soil fertility (2nd), application of complex fertilizers at basal and straight fertilizers in split up with recommended doses reduce the pest and disease incidence, creation of alley ways to control BPH, weed management by using recommended herbicides, mid season drainage (3rd), seed treatment, transplantation of lesser seedlings with shallow transplantation(4th), soil sample collection, soil test based fertilizer application, weed management in nursery, usage of post emergence herbicides(5th), direct seeding in rice reduces seed rate, labour requirement and lesser crop period with lesser cost of cultivation(6th), etc. The non adopted KVK farmers had low level of knowledge on direct seeding and SRI cultivation.

It is visible from the Table 1 that majority of the adopted rice farmers had high level of knowledge where as non adopted farmers had medium level of knowledge. The item analysis of level of knowledge of adopted rice farmers indicates that majority of them had high knowledge on hybrid and varietal seed production followed by chemical weed management, improving soil fertility with green manures, BPH control with the alleys, collecting the soil samples, soil test based fertilizer application, etc. The reasons for high level of knowledge on these technologies could be suitability of the agro ecosystem of Karimnagar district for hybrid and varietal seed production, as this was clearly envisaged by the KVK Scientists to the rice farmers. Realising the ill effects of continuous application of inorganic fertilizers, the farmers were resorted to the application of green manures to improve the soil fertility. The continuous organization of farmers field school, farmer – scientist interactions, field days and focused group discussions by the KVK scientists resulted in formation of alleys in rice crop to control the BPH, the farmers were experienced through a series of method demonstrations conducted by KVK Scientists on methods of collecting the soil samples for testing. The farmers were empowered and enriched on necessary competencies to apply the need based fertilizers based on the results generated from soil testing as it gives more economic returns. The adopted rice farmers had lowest level of knowledge on aerobic rice due to non availability of tractor drawn seed cum ferti drill.

It could be witnessed from Table 4 that the non adopted rice farmers had high level of knowledge on hybrid and varietal seed production followed by green manuring for soil fertility, applying the complex fertilizers at basal and straight fertilizers in split doses, formation of alleys to control the BPH, chemical weed management, mid season drainage, seed treatment, etc. The non adopted rice farmers of

KVK are seldom inspired and motivated and influenced by the actions and deeds of their fellow adopted rice farmers. These non adopted farmers want to replicate the successful practices carried by the adopted farmers. Hence, the same level of knowledge of adopted farmers on these technologies is reflected in case of non adopted farmers also. The seed of green manure crops is provided on subsidized rate to the farmers by the government, hence more knowledge. The non-adopted rice farmers had low level of knowledge on direct seeding and SRI cultivation due to lack of interest, motivation and inspiration.

CONCLUSION

High level of knowledge of rice production technologies was seen among the farmers adopted by the *KVK*, Jammikunta compared to the non adopted farmers. This could be due to the multiplicity of the transfer of technology mechanisms followed by the *KVK* scientists in the adopted villages

especially for the benefit of farmers adopted by the *KVK*.

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INTER TEMPORAL VARIATIONS IN SEX RATIO IN INDIA: STATE WISE ANALYSIS

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Sex ratio is an important social indicator to measure the extent of equity between males and females in any society. In India, it has been observed that millions of male population has been outnumbering the female population. The report of 2011 Census of India shows 940 females per every 1000 males (source: censusindia.gov.in). According to Sen (1990), in countries where women and men receive similar care the ratio is about 1005. This problem of low sex ratio has further been aggravated by low and the declining child sex ratio across all states of India since 1961. Studies have provided evidence that it is excessive female mortality before birth, at birth, in infancy and in childhood, which mainly account for the imbalance in sex ratios and missing of large number female children (UNICEF, 2014). This increasing gap between boys and girls especially in the age groups of 0-6 years gives us a better picture of overall sex ratio and also the status of girl child in Indian environment. The Northern and Southern states exhibit considerable differences. While the north has lower levels of literacy and per capita income levels, the south generally exhibits higher literacy levels, high per capita income levels, better health facilities and higher female participation rates. Studies have documented correlations of low sex ratios at birth with higher education, social class and economic status. Objectives of the study are to examine the trends in overall sex ratio and child sex ratio across different states of India; to analyse the effect of child sex ratio on overall sex ratio; to identify the underlying causes of changes in child sex ratio

and overall sex ratio. Trends in overall sex ratio (OSR) and child sex ratio (CSR) and literacy levels are examined across selected states of India with the help of various Census Reports. The data on per capita income is obtained from Economic Survey of India (Source: www.indiastat.com). The following regression models are specified to find out the effect of child sex ratio on overall sex ratio.

$$\text{Model 1: } OSR_i = \alpha_1 + \alpha_2 CSR_i + u_i \quad \text{—————1}$$

Where OSR = overall sex ratio; CSR = Child sex ratio; α_1 and α_2 are parameters

$$\text{Model 2 : } OSR_i = \beta_1 + \beta_2 CSR_i + \beta_3 PI_i + u_i$$

Where OSR = overall sex ratio; CSR = child sex ratio; PI = Per capita income; $\beta_1, \beta_2, \beta_3$ are parameters

Trends in Sex Ratio: The low sex ratio before 1991 was mainly due to the sex differentials in mortality (Visaria, 1971). According to him, the contributions of migration, under enumeration of females and sex ratios at birth are having only a marginal influence. The overall sex ratio has shown a secular-declining trend except some marginal increases in the censuses of 1951, 1981 and 2001. The sex ratio in 2011 was 940, seven points higher than the sex ratio of 933 recorded in 2001. Although there was a marginal increase in general sex ratio at the national level in 1981 and 2011, the child sex ratio has been continuously declining for the last five decades from 976 in 1961 to 914 in 2011. It is observed that up to 1991 the child sex ratio is more than overall sex ratio. However, reversal of that trend can be observed from 2001 census onwards (Table 1).

Table 1. Sex Ratio in India

Census Year	Overall Sex Ratio (Females per 1000 Males)	Child sex ratio (0-6 years)	Difference between child sex ratio and overall sex ratio
1951	946	-	-
1961	941	976	+35
1971	931	964	+33
1981	935	962	+27
1991	927	945	+18
2001	933	927	-06
2011	940	914	-26

Source: Office of the Registrar General and Census Commissioner, India

The child sex ratio is more than the overall sex ratio up to 1991. Between 1961 and 1991 the supremacy of child sex ratio declined from 35 points to 18 points but still higher when compared to overall sex ratio. It was in the year 2001 that the child sex ratio deteriorated and by 2011 there was a huge gap of 26 points. The child sex ratio has not only been falling but also from 2001 onwards it has been falling short of overall sex ratio and more steeply in 2011 (Table 1). Socio-cultural discrimination against female children is the main reason for female mortality mainly

because of life-sustaining inputs like food, nutrition, health care were denied to girl child (Miller, 1981). The overall sex ratio has exhibited a declining trend in all regions except in Northern and southern part of the country. In North India, the sex ratio is lowest and remained lowest throughout the period under consideration. Maximum improvement in overall sex ratio can be observed in north India followed by south India. In fact, in other regions the sex ratio has shown a decline (Table 2).

Table 2. Overall Sex Ratio of Different Regions of India

Regions	Census Year							Change between 2011 and 1951
	1951	1961	1971	1981	1991	2001	2011	
South India	997	989	982	987	986	997	1010	13
North East India	966	941	920	918	921	940	959	-07
North India	768	785	801	808	827	821	866	98
East India	962	961	945	945	929	942	947	-15
Central India	985	970	959	959	949	955	961	-24
West India	985	962	939	943	936	931	934	-51
India	946	941	930	934	927	933	940	-06

Source: www.indiastat.com

INTER TEMPORAL VARIATIONS IN POPULATION SEX RATIO IN INDIA

Child sex ratio is found to be highest in north eastern region in all the census years. Except north India, all other regions have exhibited declining trend with almost same magnitude of change between 2011 and 1991 (Table 3). Based on the spread of the data the states are categorized into high, medium and low levels of sex ratio. All four southern states fall under the category of high sex ratio with regard to overall sex ratio but with regard to child sex ratio these states could not occupy the same category

except Kerala. Along with the southern states four north eastern states (Tripura, Mizoram, Meghalaya and Manipur) fall under the category of high sex ratio states. This shows that the southern and north eastern states have been doing fairly well in terms of overall and child sex ratio when compared with other states. Almost all northern (Haryana, Punjab, UP, Jammu & Kashmir) and western states (Rajasthan, Maharashtra, Gujarat) are under the category of low sex ratio states (Table 4).

Table 3. Child Sex Ratio (0-6 years of Age) in India : Region Wise

Regions	Census Year			Change between 2011 and 1991
	1991	2001	2011	
South India	960	954	948	-6
North East India	978	969	956	-13
North India	916	866	870	4
East India	966	954	940	-14
Central India	962	952	938	-14
West India	938	909	896	-13
India	945	927	914	-13

Source: Office of the Registrar General and Census Commissioner, India.

Table 4. Status of different states as per the overall Sex Ratio and Child Sex Ratio (2011 Census)

Overall Sex Ratio		Child Sex Ratio	
Status	States	Status	States
High (above 960)	AP*, Karnataka, Kerala, Tamilnadu, Manipur, Meghalaya, Mizoram, Tripura, Himachal Pradesh, Uttarakhand, Orissa, Chattisgarh, Goa	High (above 950)	Kerala, Arunachal Pradesh, Assam, Meghalaya, Mizoram, Tripura, Chattisgarh, West Bengal
Moderate (between 960 to 940)	Assam, West Bengal, Jharkand	Moderate (between 950 to 914)	AP, Karnataka, Tamilnadu, Manipur, Nagaland, Bihar, Jharkand, Orissa, Goa
Low (below 940)	Arunachal Pradesh Nagaland, Haryana, Jammu & Kashmir, UP, Punjab, Delhi, Bihar, MP, Gujarat, Maharashtra, Rajasthan	Low (below 914)	Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, UP, Uttarakhand, MP, Rajasthan, Gujarat, Maharashtra

*United AP

Table 5. Overall Sex Ratio of major states of India

Region	State	1991	2001	2011	Change Between 1991 and 2011
South India	Andhra Pradesh	972	978	992	20
	Karnataka	960	964	968	8
	Kerala	1036	1058	1084	48
	Tamil Nadu	974	986	995	21
North India	Haryana	865	861	877	12
	Punjab	882	874	893	11
	Uttar Pradesh	876	898	908	32
East India	Bihar	907	921	916	9
	Orissa	971	972	978	7
	West Bengal	917	934	947	30
West India	Gujarat	934	921	918	-16
	Maharashtra	934	922	925	-9
	Rajasthan	910	922	926	16
Central India	Madhya Pradesh	912	920	930	18

Source: Office of the Registrar General and Census Commissioner, India.

Among the southern states only Kerala achieved highest overall sex ratio and also highest improvement between 1991 to 2011. The least improved sex ratio state is Orissa during the same period (Table 5).

With regard to child sex ratio almost all states performed low only with the exception of Kerala and Tamilnadu. In these states, the child sex ratio is almost constant between 1991 and 2011. The fall in child sex ratio is very steep in western and northern states (Table 6). There is hardly any state, which has child sex ratio of 1000 or more. It can be inferred that the sex ratio imbalances are more severe in the north western region, which stretching from Uttaranchal in the north runs up to Maharashtra in the west across Himachal Pradesh, Punjab, Chandigarh, Haryana, Delhi, Rajasthan and Gujarat. This decline has also been steep in the northern region. Kerala is the only state recorded a favorable sex ratio for females. Many research works have been carried out in finding out the answers for continuous fall in sex ratio in India. Recent studies of female

infanticide, new biases in sex ratios at birth and infant and child mortality rates indicate that extreme forms of daughter discrimination resulting in death have persisted (Miller, 1989). The hypotheses tested is that as the child sex ratio declines, the overall sex ratio also declines unless the health conditions of the adult females improves as a result of increase in incomes. This hypothesis is tested with the help of two models. Model 1 uses the change in child sex ratio as independent variable and change in overall sex ratio as dependent variable.

The results of the Model 1 are as follows:

$$\Delta OSR_i = 33.965 + 0.6549 \Delta CSR_i$$

$$t \text{ value } (3.34) \quad R^2 = 0.497$$

The results show that for every 10 points decline in child sex ratio resulted in fall in overall

Table 6. Child Sex Ratio (between 0-6 Years) for major states of India

S. No.	State	1991	2001	2011	Change Between 2011 and 1991
South India	Andhra Pradesh	974	964	943	-31
	Karnataka	960	949	943	-17
	Kerala	958	962	959	1
	Tamil Nadu	948	939	946	-2
North India	Haryana	879	820	830	-49
	Punjab	875	793	846	-29
	Uttar Pradesh	928	916	899	-29
East India	Bihar	959	939	933	-26
	Orissa	967	950	934	-33
West India	West Bengal	967	963	950	-17
	Gujarat	928	878	886	-42
	Maharashtra	946	917	883	-63
	Rajasthan	916	909	883	-33
Central India	Madhya Pradesh	952	929	912	-40

Source: Office of the Registrar General and Census Commissioner, India.

sex ratio by 6.5 points. The coefficient of change in child sex ratio is found to be significant at 1% level. The proposed hypothesis is that in states where the expected sex ratio is falling short of observed sex ratio the female expectancy levels are expected to be high with the high levels of nutrition and health care due to the high levels of state's per capita income. The reverse is true for other relatively poorer states. The Table 6 shows that in poorer states such as Bihar, Uttar Pradesh and Madhya Pradesh the expected sex ratio is much higher than the observed sex ratio. As per the Model results if the child sex ratio falls by 10 points the overall sex ratio should also fall by the same extent. However, the overall sex ratio has fallen short of expected by 54 points mainly due to low nutritional levels and health care. This result motivated us to estimate Model 2 which also includes per capita income in addition to child sex ratio.

The estimated equation in Model 2 : $OSR = -252.917 + 1.2560 CSR + 0.00144 PI + e_i$

t value (5.9945) (2.6538) $R^2 = 0.766$

The results clearly indicate that after including the per capita income in the Model the results have improved both in terms of level of significance and also in terms of overall fit of the model. The coefficients of child sex ratio and per capita income are found to be significant at 1% level. This model shows that if the child sex ratio falls by 10 points the overall sex ratio also falls more than proportionately and if the per capita income increases by ten points the overall sex ratio also increases by one point. The trends that observed both in overall sex ratio and child sex ratio in India are alarming and cause for concern especially in northern and western states. The decline in child sex ratio is observed in states where the per capita income is

high which is a cause for concern and needs immediate attention of policy makers and the government.

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