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- To provide a platform for exchange of knowledge and information on rice research and developments through organizing workshops, symposia, conferences, etc.,
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- To facilitate research and Industry collaboration and public private partnership at national level.
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Invited Paper

Site Suitability Analysis of SRI (System of Rice Intensification) Cultivation in Potential Rice Cropped Areas of Andhra Pradesh: A Geospatial Approach

Anima Biswal*, M.V.R. Sesha Sai,, K.V. Ramana, S.V.C. Kameswar Rao and G. Sujatha

Agricultural Sciences Application Group, Soil & Land Resources Assessment Division, National Remote Sensing Centre, ISRO, Hyderabad, Andhra Pradesh

Abstract

The study was undertaken to characterize the soils of Andhra Pradesh, India, for soil-suitability evaluation for SRI (System of Rice Intensification) cultivation in potential rice cropped areas using remote sensing and geographic information system based multi criteria evaluation. The soil attributes selected for suitability analysis for SRI rice are soil drainage, soil depth, soil texture and soil salinity. The study clearly brought out the spatial distribution of rice crop derived from remote sensing in conjunction with evaluation of soil suitability for SRI method of rice cultivation. The study indicates that about 21.67 lakh ha. of potential rice area is highly suitable for SRI followed by 11.41 lakh ha. of moderately suitable area. A marginal area of 37,102.96 thousand ha. was identified as slightly suitable for SRI method of rice cultivation in Andhra Pradesh.

*Corresponding author: anima.biswal@gmail.com

Key words: Site suitability, SRI, geospatial approach, remote sensing, GIS.

The System of Rice Intensification (SRI) is a method of rice cultivation that involves efficient utilization of natural resources along with judicious use of external inputs to produce optimum rice yields. SRI is a method of agronomic management of rice cultivation for increasing the yield of rice per unit area per unit time with reduced seed and water requirement and modified soil (field) ecosystem with special and mechanical arrangements. This improved method of rice cultivation was developed in 1983 in Madagascar by Fr. Henri de Lau Lanie in association with a non government organization – Association Tefy Saina (ATS) and with many small farmers which has later spread to many countries. SRI cultivation is a system rather than a technology and is based on the insights that rice has the potential to produce more tillers and grains than conventional method and that early transplanting and optimal growth conditions, spacing, humidity, biologically active and healthy soil and aerobic soil conditions during vegetative growth can fulfill this potential. Major SRI principles include: (1) raising seedlings in well managed nurseries (2) careful transplanting of single and young (8–15 days old) seedlings at wide plant spacing (starting at 25 x 25 cm, but going up to 50 x 50 cm) (3) intermittent application of irrigation to avoid permanent flooding during the vegetative growth phase (4) addition of nutrients to the soil, preferably organic manures and amendments instead of chemical fertilizer (5) intensive manual or mechanical weed control without the use of herbicides. Sridevi and Chellamuthu (2012) reported that when all these principles are followed, it profoundly enhanced the growth and nutrient uptake which in turn improved the yield attributes and yield. The enhancement in the performance of rice was linearly proportional to the number of SRI components being practiced. As the SRI components increase, the performance of rice enhances. SRI that evolved in the 1980s in Madagascar is also gaining popularity in India. SRI saves not only the seed (a seed rate of 5–7 kg/ha as against 25–30 kg/ha for normal) but also saves water (35–40%) as the fields are not inundated continuously (Ghritlahre *et al.*, 2012; Nay-Htoon *et al.*, 2013;Thakur *et al.*, 2010). Rice is the major crop under canal, tank, and tube well irrigation systems in AP, with groundwater-based systems now constituting 50% of the gross irrigated area in the state. The normal practices of rice cultivation include transplanting seedlings about 25 days old, with a seed rate of 60-75 kg ha^{-1}, and continuous inundation of water until the grain filling stage. The large-scale shift from canal and tank irrigation to reliance on wells has placed stressful demands on the state's groundwater resources, with extraction exceeding recharge rates in several parts of Andhra Pradesh. The System of SRI was diffused first to Tamil Nadu State in India during the year 1999 (Johnson and Vijayaragavan, 2011; followed by Andhra Pradesh with systematic evaluation in on-farm comparison trials across all districts of the state. Although SRI has not spread across the state on a large scale, experiences in a number of areas can be assessed for its potential adaptation. Andhra Pradesh (AP) is among the several states considered as 'SRI-adopting' and hence, its diffusion process is of scientific interest. Ravindra and Laxmi, (2011) evaluated the Potential of the system of rice intensification for systemic improvement in rice production and water use in Andhra Pradesh. Scientists from the Directorate of Rice Research, Hyderabad conducted field experiments from 2008 to 2010 and concluded that SRI practices creates favourable conditions for soil microbes to prosper, save irrigation water and increase grain yield (Gopalakrishnan *et al.,* 2013). SRI can become a viable alternative approach to the conventional transplanting having advantage of both in terms of higher yield and water productivity especially, in the areas of limited water situations (Kumar *et al.,* 2011).

Suitability is a function of crop requirements and land characteristics (Mustafa *et al.,* 2011). In order to explore the potential areas suitable for SRI, knowledge of soils, their properties, and spatial distribution is indispensable as it opens opportunities for a more rational management of the soil resources. Development of a GIS-based thematic database on soils is vital in crop-suitability analysis for optimal utilization of available resources (Coleman and Galbraith, 2000). Weighted overlay analysis is a component of spatial modeling using spatial multi-criteria evaluation. Weighted overlay analysis assigns more importance to some criteria over others (Hailegebriel, 2007; Zelalem, 2007). Multi-Criteria Evaluation (MCE) approaches and GIS is useful because various production variables can be evaluated and each weighted according to their relative importance on the optimal growth conditions for crops (Perveen *et al.,* 2007). In the present study, multi-criterial overlay analysis was carried out for soil site suitability for SRI method of rice cultivation in the potential rice growing area of Andhra Pradesh using GIS and remote sensing techniques.

Study area

Andhra Pradesh is selected for this study in order to evaluate the soil suitability classes for potential adaptation of SRI in the existing rice area. The state has 13.83 million ha of gross cropped area out of which 4.82 million ha is the net irrigated area with an irrigation intensity of 1.39 (2008-2009). In Andhra Pradesh, rice is grown in 22 districts, out of which 14 districts are falling under high productivity group, that is, yield more than 2500 kg/ha. More than 85 per cent of rice in the State is grown under different sources of irrigation under puddle condition whereas out of the rest, 10 per cent rice area lies in the rain-fed low land ecosystem and 5 per cent in the rainfed system.

Materials and Methods

For carrying out the soil suitability analysis, a geo-referenced digital soil map with attributes like drainage, texture, depth and salinity, etc., is required that could be used as a reference map. For this study, NBSSLUP soil map of 1:250,000 scale is used. The digital soil map of AP consists of 1249 polygons linked with an attribute table. Lambert Conformal Conic projection and Geographical coordinate system with WGS 84 datum was used in ARC GIS to generate all the thematic layers. The attributes selected for suitability analysis for SRI rice are: (1) Soil drainage (2) Soil depth (3) Soil texture (4) Soil salinity. The suitablity criteria of these properties are evaluated independently prior to jointly ranking them followed by multi criteria overlay analysis in GIS. The detailed methodology is presented in Fig. 1.

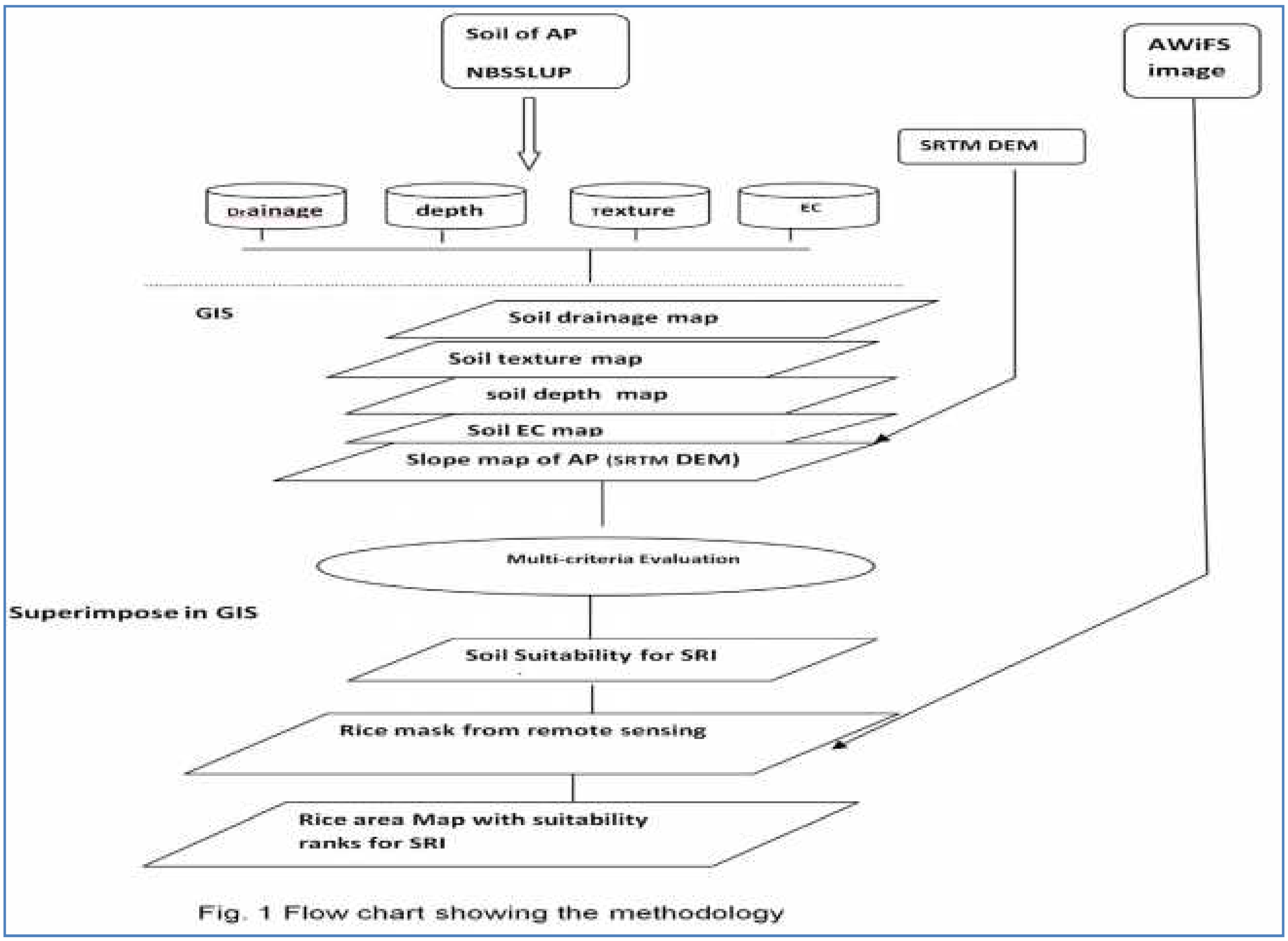

Fig. 1 Flow chart showing the methodology

Satellite DataAWiFS (Advanced Wide Field Sensor)

Potential rice area mask was generated using IRS-P6 (AWiFS) images. IRS-P6 (AWiFS) has a spatial resolution of 56 m, four spectral channels (green (0.52–0.59µm), red (0.62–0.68µm), near infrared (NIR: 0.77–0.86µm) and short-wave IR (SWIR: 1.55–1.70µm)) and a temporal resolution of 5 days with a 740 km swath width. Time series AWiFS images pertaining to the study area were processed in ERDAS IMAGINE software. AWIFS images were geo-referenced with Survey of India (SOI) topographic map (1:250,000). With ground truthing, supervised classification was carried out using maximum likelihood algorithm. The accuracy of the classification was evaluated using classification error matrix. Potential rice area mask was generated and overlaid on the soil suitability map to derive the rice area suitability for adaptation of SRI method in Andhra Pradesh.

DEM (Digital Elevation Model)

Shuttle Radar Topography Mission (SRTM) derived DEM of 90 m resolution was used to generate the slope map of AP. The data were taken from http://srtm.usgs.gov/data/obtaining.html. The study area was clipped, projected and then imported to the ArcGIS. Based on the data the slope map was generated.

Results and Discussion

Generation of thematic database in GIS

The rice growing soils in AP are varying in properties such as texture, drainage, pH, water holding capacity and nutritional status, etc. These soils are in various topographical, pedological and hydrological conditions in various land-forms. The most useful application of GIS in resource data analysis is to overlay various thematic maps to derive useful results. The factors which could influence soil-suitability evaluation for SRI have been defined and thematic layers on soil drainage, depth, texture, salinity and slope were generated. The present study has utilized the analytical capabilities of GIS in the evaluation of soil suitability for SRI method of rice cultivation in Andhra Pradesh.

Assigning weight and Multi Criteria Evaluation (MCE)

The purpose of weighting is to express the importance or preference of each factor relative to the other factor on SRI method of rice cultivation. Factors established in this phase are not unique but they are most relevant and expert opinion is very important in this phase. Suitability levels for each of the above mentioned factors were defined and ranks were attributed accordingly. Once the composite layers and their weights were obtained, the multi criteria evaluation was carried out in GIS environment to produce the soil suitability maps for SRI method of rice cultivation in Andhra Pradesh.

Soil drainage

The wetting and drying cycles are regarded as critical to yield performance, with the intermittent drying promoting root development in a way that is not possible under a 'wet' regime. Hence, soil drainage is the most important physical attribute of soil for SRI method. Soil drainage classes derived from NBSSLUP soil map of 250,000 scale is shown in Fig. 2. Though there are five drainage classes altogether, for this study the soils of AP were categorized into three drainage classes according to the suitability for SRI method of rice cultivation.

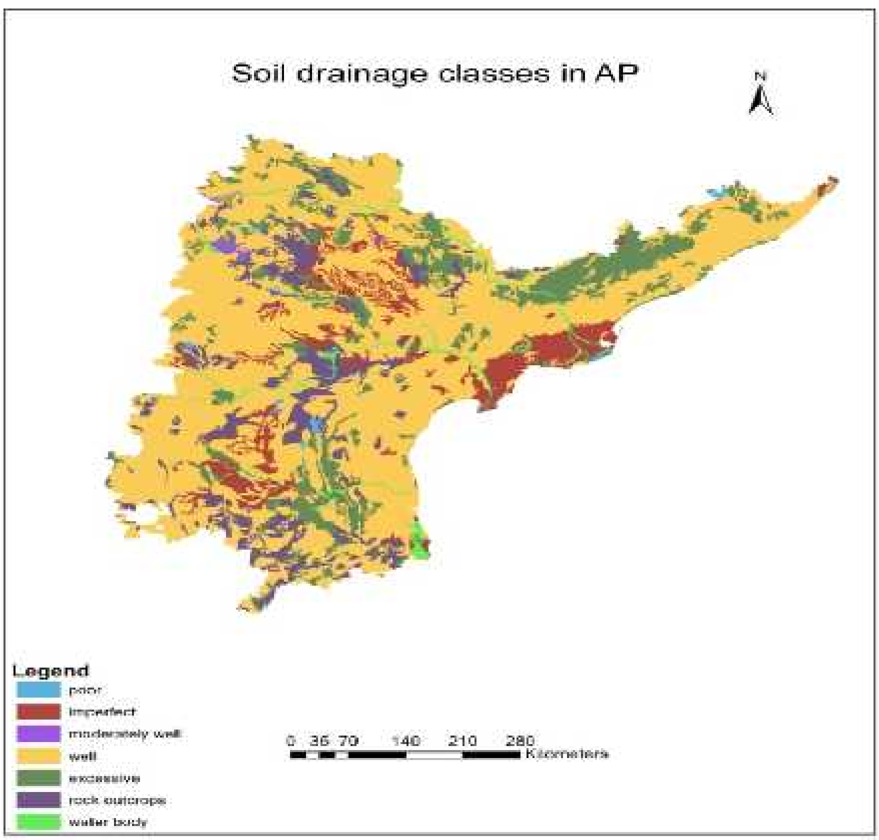

Fig. 2: Soil drainage classes in AP

The poorly drained soils are sparsely distributed particularly in the north eastern and central part of AP. The well drained soils are given lowest weight of 1 (most suitable), the moderately well drained as well as the imperfectly drained soils are given a weight of 2 and lastly, poor and excessive drainage classes are attributed the highest weight of 3 (least suitable). When the drainage map is overlaid on the potential rice map, it was found that approximately 24.24 lakh ha of rice area is well drained and best suitable for SRI, followed by moderately well drained class of approximately 6.82 lakh ha. and approximately 2.38 lakh ha. of poorly drained soil.

Soil depth

Soil depth is one of the most important soil physical parameters for SRI method of rice cultivation. Soil depth determines roots growth as well as presence of volume of water and air in the soil. In shallow soil, the crops suffer sub optimal conditions in the limited soil volume, which hinders growth and yield of the crop. The depth limitations also vary with the kind of clay mineral present. According to the soil map of 250,000 scale, the soils of AP are categorized into four classes as shown in the Fig. 3. Maximum area of AP is covered by deep soil. For studying the soil suitability for SRI method of rice cultivation, the soils of AP were categorized into two depth classes, and it is observed that most of the rice area in AP are deep or moderately deep. The shallow and very deep soils are sparsely distributed throughout AP. As intermittent irrigation is practiced in SRI during vegetative growth to keep the soil just saturated or moist enough to avoid drought stress, the deep/moderately deep soils are given lowest weight of 1 (more suitable) and shallow as well as very deep classes are attributed the weight of 2 (less suitable). It was observed that most part of potential rice cropped area of approximately 30.836 lakh ha. is more suitable to SRI method and approximately 2.529 lakh ha. is less suitable when soil depth is considered alone.

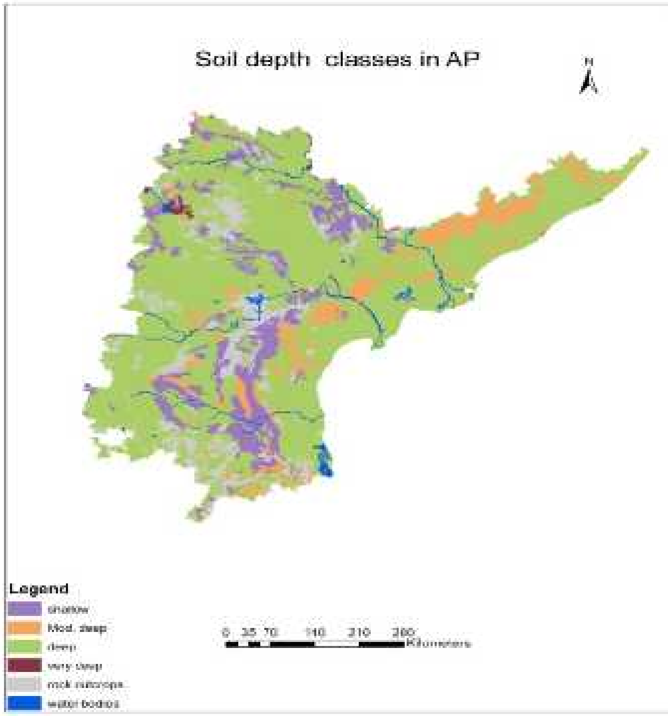

Fig. 3: Soil depth classes in AP

Soil texture

Soil texture has a large influence on irrigation water requirement due to much higher percolation losses on coarser textured soils. Hence, soil texture is an important parameter for rice system. According to the soil map of 250,000 scale, the soils of AP are categorized into five textural classes as shown in the Fig. 4. Clayey soil covers the maximum area. As physical condition of soil is very important criteria for SRI and well drained soil is preferred, the soils of AP categorized into three texture classes for this study. It was observed that approximately 7.925 lakh ha. of rice area is covered with best suitable soil texture (loamy and clay skeletal) for SRI and the maximum rice area of approximately 23.343 lakh ha. is moderately suitable for SRI as far as soil texture is concerned. Approximately 2.231 lakh ha. rice area is with poor soil texture which might cause poor or excessive drainage.

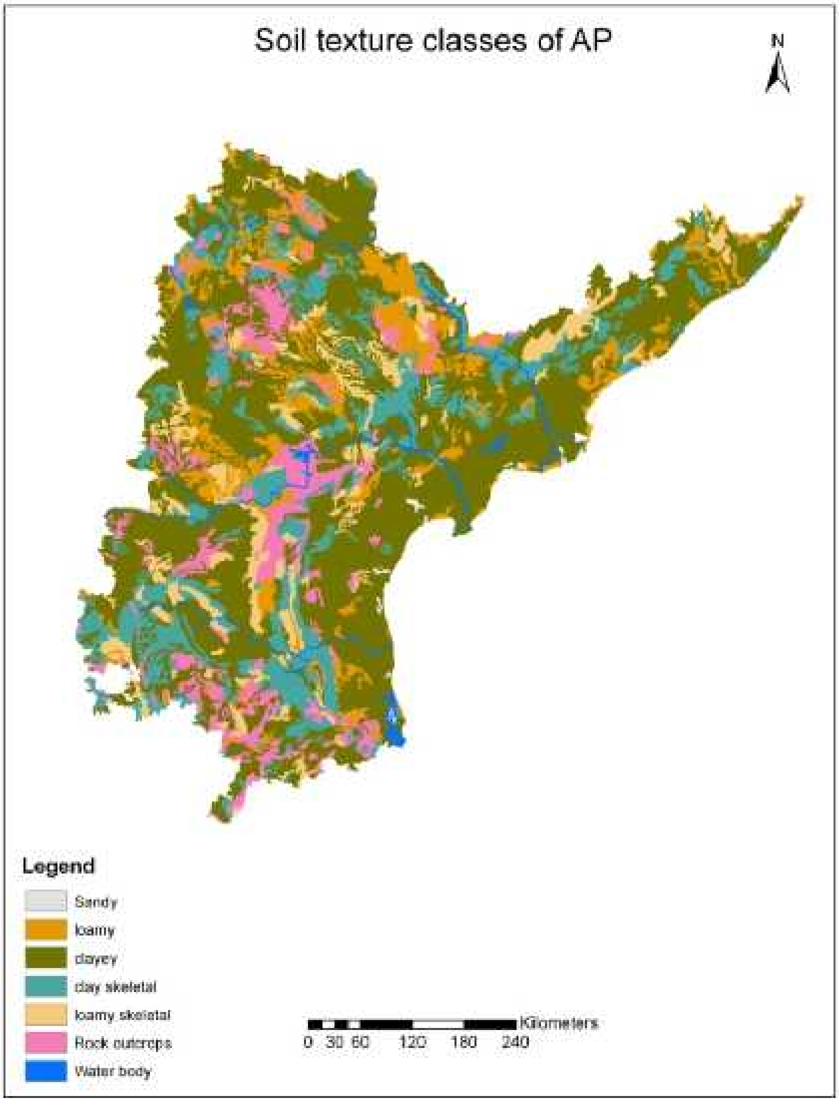

Fig. 4: Soil texture classes in AP

Loamy and clayey skeletal texture classes are attributed a weight of 1 as they are well suited for SRI, clayey texture is given a weight of 2 which is moderately suitable and sandy, loamy skeletal texture classes are attributed a weight of 3 which are least suitable due to excessive drainage and low water retention properties.

Soil salinity

As shown in Fig. 5, there are 6 salinity classes in the NBSSLUP soil map of 250,000 scale and normal soil occupies most of the area in AP. As high saline soils are not suitable for SRI system, the soils of AP categorized into two salinity classes for this study. It is observed that entire rice area of approximately 33.091 lakh ha. is non saline where as 21,487 thousand ha. rice area is having moderate to strong salinity problem.

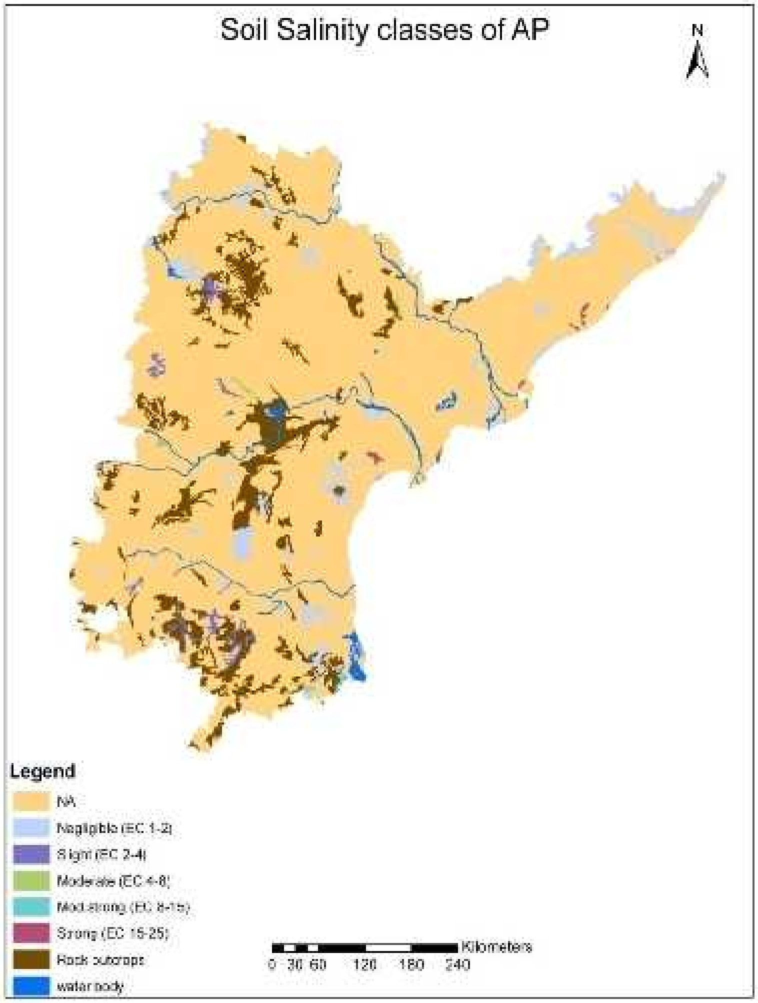

Fig. 5: Soil salinity classes in AP

Slope

Slope map was generated from the SRTM derived DEM of 90m resolution for the state of AP and presented in Fig. 6. It is observed that most of the potential rice grown area in the state is lying on the flat terrain with slope less than 15 degree. As far as potential rice grown area of AP and adaptation of SRI based on soil criteria are concerned, the slope effect is not significant.

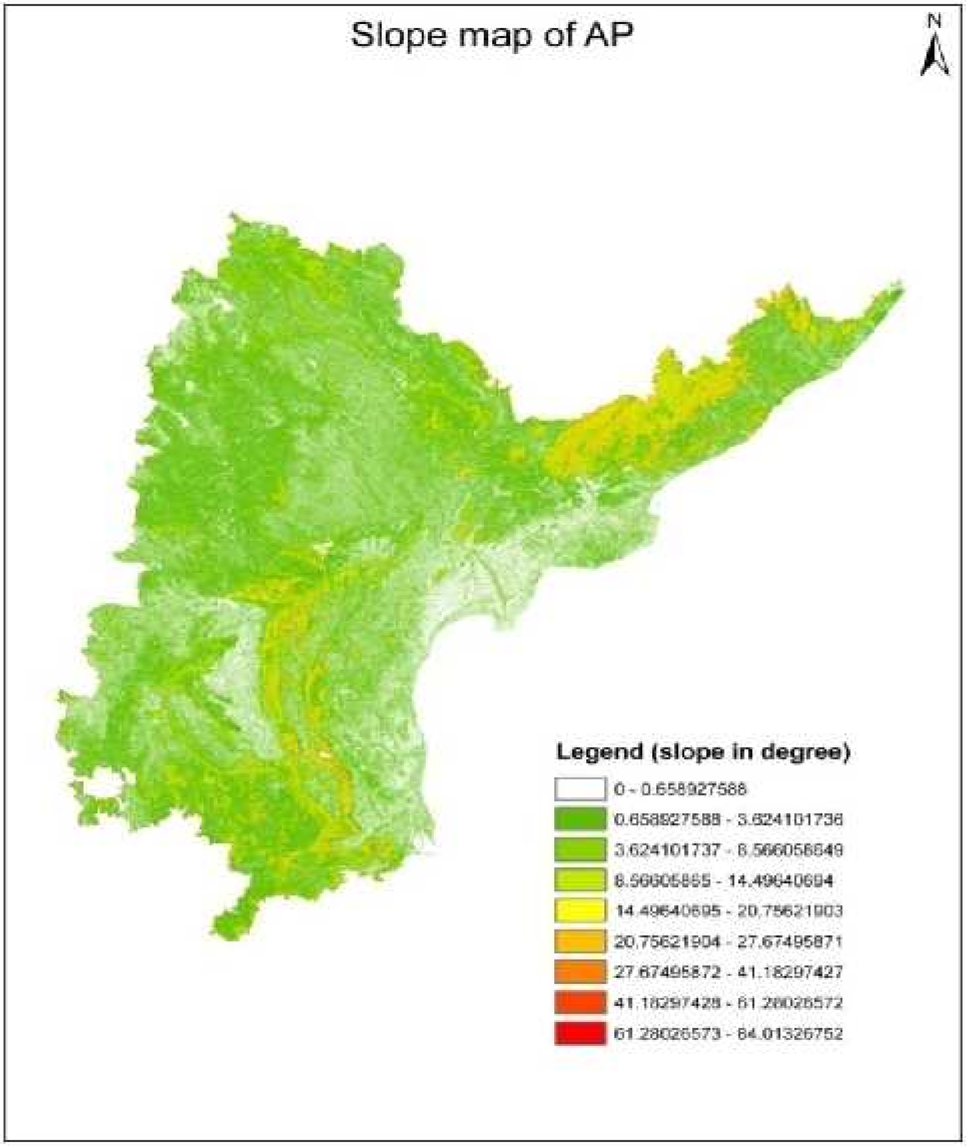

Fig. 6: Slope map of AP

Multi criteria Evaluation for soil suitability analysis for SRI system

After preparing thematic maps and giving weightage to the respective soil parameters according to the soil suitability for SRI method of rice cultivation, multi-criteria evaluation was carried out in GIS to arrive at suitability classes. Four soil criteria along with their associated categories (3x3x2x2) are considered resulting in 36 possible combinations with total weightage ranging from 4 to 9. As more suitable classes are attributed lower weightage, the final weightage of 4-5 are grouped into the highly suitable class (S1) followed by moderately suitable class (S2) with weightage 6-7; and slightly suitable (S3) with weight 8-9 (Table 1). It is to be noted that, as our analysis is confined to the potential rice grown area in the state, only the rice area with different suitability classes for SRI is shown in the map (Fig.8). The potential rice cropped area derived from AWiFS images (Fig.7) was overlaid on the soil suitability map and the extent of each suitability class was calculated. It is observed that most of the rice area is best suitable for SRI followed by moderately suitable class. A very small fraction of rice area is found slightly suitable for SRI method of rice cultivation. Negligible area was classified as non suitable class.

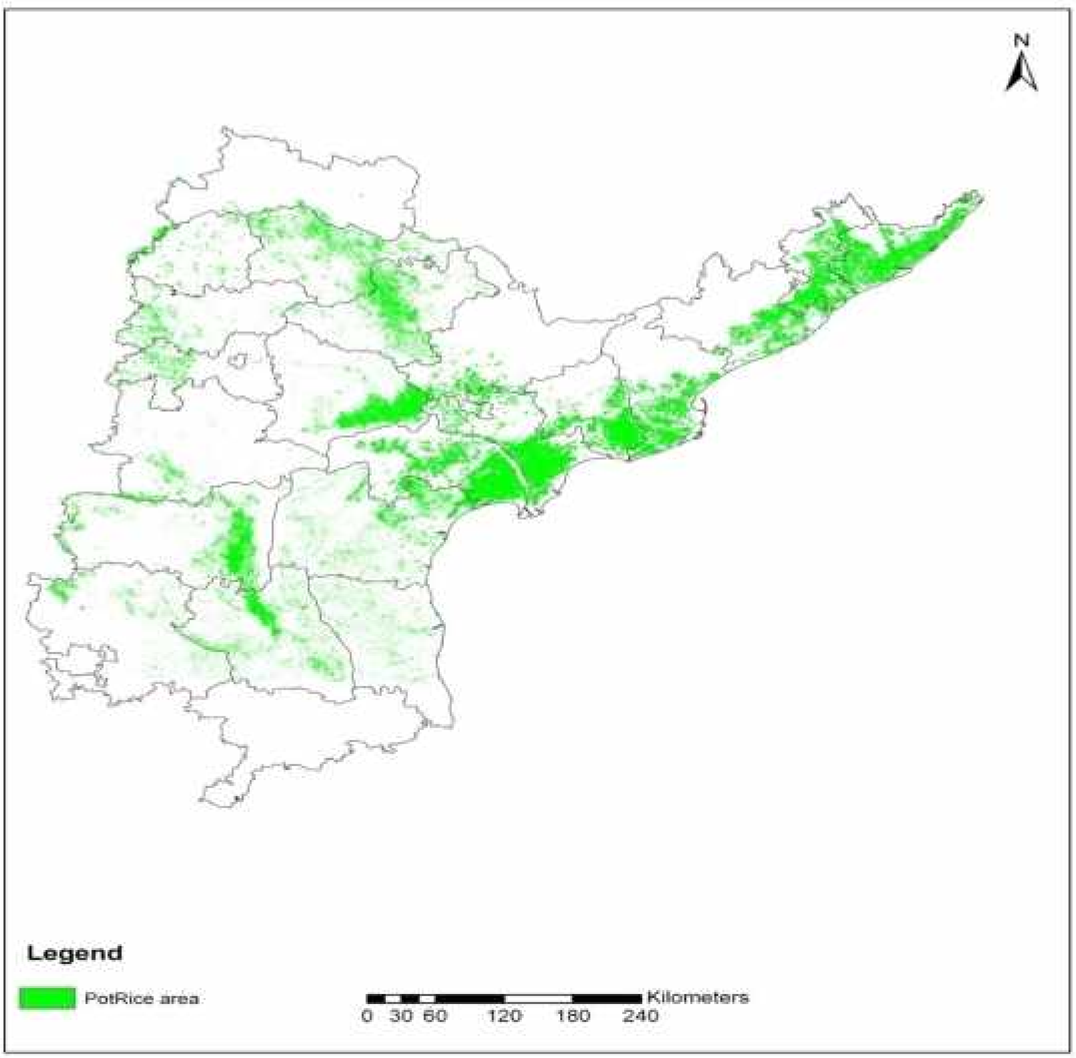

Fig. 7: Potential Rice area derived from AWiFS

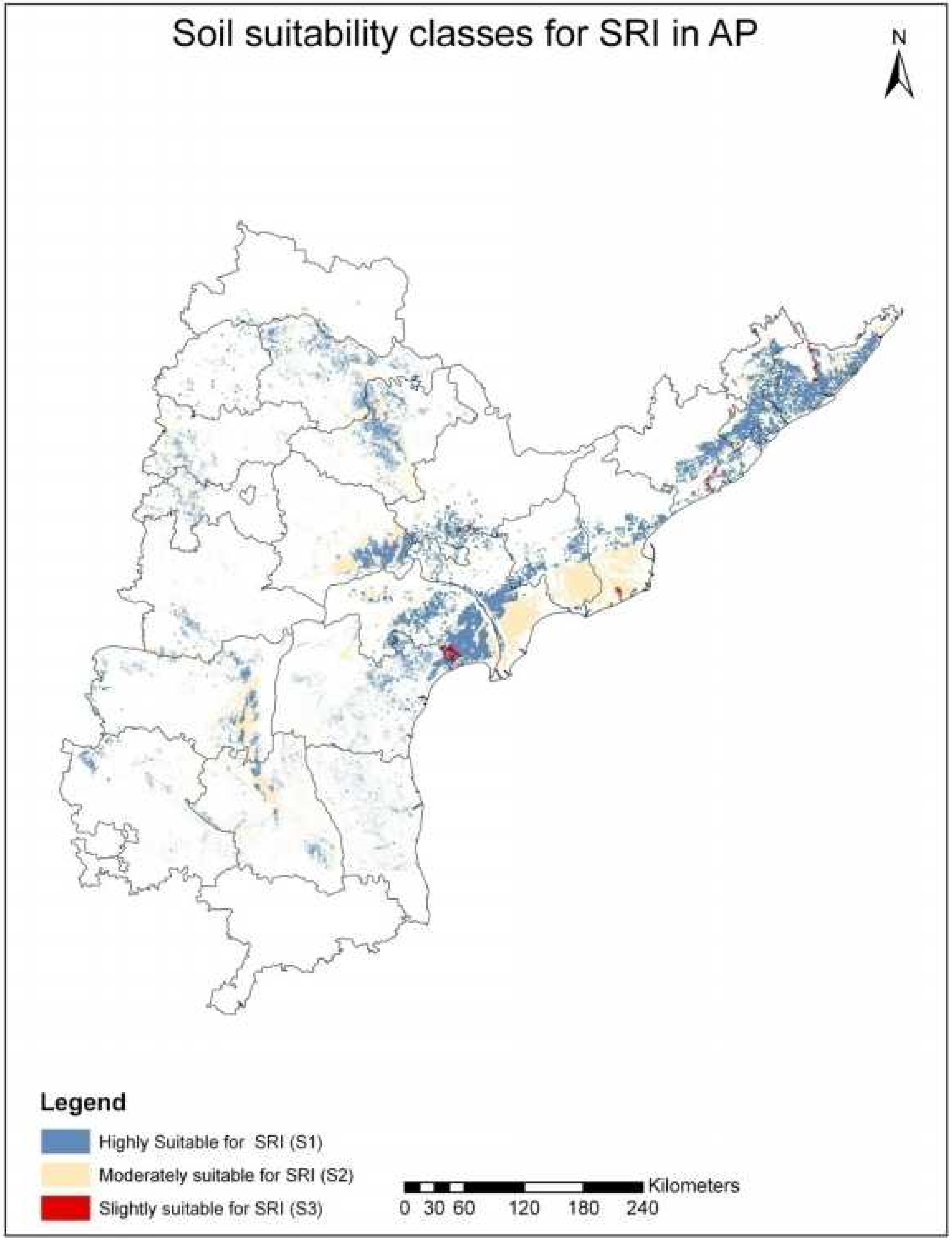

Fig. 8: Soil suitability classes for SRI in AP

Conclusions

In this study, Remote Sensing (RS) and GIS techniques were applied to identify suitable areas for SRI cultivation of rice in Andhra Pradesh, based on soil criteria. The results obtained from this study confirm that RS, GIS and multi-criteria evaluation techniques proved to be effective tools for soil-site suitability analysis studies. The study clearly brought out the spatial distribution of rice crop derived from remote sensing in conjunction with evaluation of soil suitability for SRI method of rice cultivation. However, further studies are suggested, for including more number of soil parameters and other socio-economic data like irrigation facility etc., that affect the adaptation of SRI method of rice cultivation in the state.

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Table 1: Potenital area suitable for SRI based on multi- criteria evaluation

Rank scored in multi-criteria weight overlay analysis	Suitability for SRI system	Potential Rice Area of AP
4-5	S1;Highly Suitable	21.675 lakh ha.
6-7	S2; Moderately Suitable	11.410 lakh ha.
8-9	S3; Slightly Suitable	37,102.96 thousand ha.

Variability and Association Studies for Yield Components and Quality Parameters in Rice Genotypes

B. Krishna Veni*, B. Vijaya Lakshmi and J.V. Ramana

Rice Research Unit, ANGRAU, Bapatla, Guntur, Andhra Pradesh

Abstract

Direct selection based on crop yields is often a paradox in breeding programmes because yield is a complex polygenically inherited character, influenced by its component traits. Breeding programmes should, therefore, take into consideration character association of various component traits with yield and among themselves. In this study, seventy rice (*Oryza sativa* L.) genotypes were assessed for genetic variability and correlations between yield and yield components and quality parameters. A wider genetic variability was observed among the genotypes for most of the characters studied. Days to 50 per cent flowering, productive tillers per plant, panicle length, Head Rice Recovery (HRR) and volume expansion ratio manifested significant positive association with grain yield indicating that simultaneous improvement of all the characters is possible. Productive tillers, panicle length, kernel breadth and L/B ratio manifested positive direct effect on grain yield per plant. The relative contribution of characters towards variability and results of correlation and path coefficient indicated the importance of days to 50per cent flowering, ear bearing tillers and panicle length.

*Corresponding author: bkv_lam@yahoo.co.in

Key words: Rice, correlation, path analysis, grain yield, quality parameters.

Rice (*Oryza sativa* L.) is the staple food for about 3.0 billion world's population which may escalate to 4.6 billion by 2050. Rice fulfills the nutritional requirements of half of the world's population. In India, rice is a major food crop supplying 30% of the calorie requirement to the Indian population (Maclean, 2002). The estimation of character association could identify the relative importance of independent character (s) that may be useful as indicator(s) for one or more characters. Similarly, path coefficient analysis partitions the genetic correlation between yield and its components into direct and indirect effects. The present study is an attempt for assessing rice genetic variability, and association of various physico-chemical quality characters with yield components and grain yield to provide basis for selection and yield improvement.

Materials and Methods

Seventy genotypes collected from various research stations were evaluated in a randomized block design with two replications during *kharif* 2010 at Rice Research Unit, Bapatla. Each genotype was raised in two rows of five meter length with a spacing of 20x15cm between and within the rows respectively. Observations were recorded on five randomly selected plants from each replication for six yield components *viz.,* days to 50 per cent flowering, plant height, productive tillers, panicle length, test weight and grain yield per plant. The quality parameters *viz.*, head rice recovery, kernel length, kernel breadth, L/B ratio, kernel length after cooking, elongation ratio, water uptake, volume expansion ratio and amylose content were estimated replication-wise on plot basis as per the standard procedures delineated by Murthy and Govinda Swamy (1967), Juliano (1971) and Little *et al.,* (1958). The mean values were utilized for the estimation of genetic parameters and genotypic correlations as per the standard statistical procedures. The correlations were partitioned into direct and indirect effects by path coefficient analysis using the technique outlined by Dewey and Lu (1959).

Results and Discussion

The analysis of variance revealed significant difference among the genotypes for all the characters studied indicating the existence of variation among genotypes for traits under study. Coefficient of variation truly provides a relative measure of variance among the different traits. GCV (Table 1) was found to be highest for water uptake (26.28) followed by grain yield per plant (26.18) and test weight (20.35). As suggested by Subramanian and Menon (1973) the remaining characters were categorized into low and moderate groups with a range of 3.42 (panicle length) to 16.96 (productive tillers/plant). Similar trend was observed for PCV also. Close relationship between GCV and PCV was found in all the characters and PCV values were slightly greater than GCV, revealing very little influence of environment for their expression. Similar results were obtained by Sharma and

Sharma (2007) and Binse *et al.* (2006). Except water uptake, all the quality traits recorded low to moderate variability estimates which corroborate with the results of Kumar *et al.* (2006) and Prasad *et al.* (2009).

Heritability and genetic advance

Heritability plays a vital role in deciding the suitability and adopting breeding strategy for improvement of a particular character. As per Johnson *et al.* (1955) classification, all the fifteen characters under study exhibited high values for broad sense heritability ranging from 97.8% (days to 50% flowering) to 62.8% (volume expansion ratio) except panicle length (34.3%) and amylose content (56.1%) which recorded low values. Although, the presence of high heritability values indicates the effectiveness of selection on the basis of phenotypic performance, it does not show any indication to the amount of genetic progress for selecting the best individuals which is possible by using the estimates of genetic advance. The estimates of genetic advance as per cent of mean was high for grain yield (52.23) followed by water uptake (49.12) and test weight (41.14) while the remaining characters manifested low to moderate values. Similar results were earlier reported by Sharma and Sharma (2007), Bhavana (2003) and Veni *et al.* (2006). High heritability coupled with high genetic advance and high GCV were observed for grain yield per plant, water uptake followed by test weight and productive tillers per plant indicating the preponderance of additive gene action and such characters could be improved through selection. The characters, panicle length and amylose content recorded low estimates for all variability parameters studied suggesting the role of non-additive gene action.

Association analysis

Complete knowledge on interrelationship of plant character like grain yield with other characters is of paramount importance to the breeder for making improvement in complex quantitative character like grain yield for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield. Days to 50 per cent flowering, productive tillers per plant, panicle length, head rice recovery and volume expansion ratio manifested significant positive association with grain yield (Table 2) indicating that simultaneous improvement of all the characters is possible. Sharma and Sharma (2007), Krishna *et al.* (2008) also reported similar findings. Days to 50 per cent flowering also exhibited a significant positive correlation with plant height (0.2709) and ear bearing tillers per plant (0.4728) while its association with L/B ratio is significantly negative. Plant height and productive tillers manifested positive and significant correlation with panicle length. The results are in corroboration with the findings of Kumar and Kannan Bapu (2005) and Krishna *et al.* (2009). Ear bearing tillers and panicle length exhibited significant positive association with head rice recovery. Kernel length (-0.2944), kernel breadth (-0.3755) and elongation ratio (0.3026) manifested significant negative association with grain yield/plant. Among quality traits, kernel length manifested significant positive association with L/B ratio (0.6244) and kernel length after cooking (0.6514) while kernel breadth exhibited significant negative correlation with L/B ratio. Significant positive correlation was observed between L/B ratio and kernel length after cooking and between kernel length after cooking and elongation ratio. Similar results were previously reported by Veni *et al.* (2006). Significant positive correlation was observed between elongation ratio and volume expansion ratio while significant negative relationship was manifested between volume expansion ratio and amylose content.

Path-coefficient analysis using grain yield as dependent variable and other characters as independent variables is presented in Table 3. Productive tillers (0.5687) manifested the maximum direct effect (0.5687) on grain yield /plant followed by kernel breadth (0.2809), L/B ratio (0.2689), KLAC (0.2286) and panicle length (0.1428). Test weight (-0.3035) and kernel length (-0.3285) exhibited negative direct effect on grain yield per plant. The results were in agreement with the previous findings of Krishna *et al.* (2008), Veni *et al.* (2003).Productive tillers manifested positive indirect effect on grain yield/plant through days to 50 per cent flowering (0.2689), panicle length (0.3147), head rice recovery (0.2353) and volume expansion ratio (0.2635). Panicle length and test weight expressed positive indirect effects through days to 50 per cent flowering, plant height and Productive tillers. Among quality traits, kernel length exhibited negative indirect effects through test weight, L/B ratio and kernel length after cooking and its correlation with grain yield/plant is also negative. The association of kernel breadth with grain yield is significantly negative but its direct effect is positive, under such conditions restricted simultaneous selection is advocated for utilization of their positive indirect effects.

The genetic architecture of grain yield is based on the balance or overall net effect produced by various yield components interacting with one another. Based on the studies on genetic variability and correlation analysis, it may be concluded that productive tillers, panicle length and days to 50 per cent flowering exhibited positive direct effect on grain yield per plant coupled with significant positive association with grain yield per plant. Hence, utmost importance should be given to these characters during selection for single plant yield improvement. Selection of plants on the basis of these traits would certainly lead to improvement in grain yield.

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Table 1: Mean, range and variability parameters for 15 yield components and quality parameters in 70 genotypes of rice

Character	Mean	Range	PCV	GCV	Heritability	Genetic advance as % of mean
DFF (days)	106.95	89-133	11.98	11.84	97.8	24.12
PH (cm)	96.88	74.5-148.0	11.33	11.12	96.3	22.48
EBT	10.42	6.75-15.52	20.02	16.96	71.7	29.59
PL (cm)	22.82	19.2-24.5	5.85	3.42	34.3	4.13
TW (g)	19.71	13.41-32.29	20.73	20.35	96.3	41.14
HRR (%)	59.72	50.3-67.1	7.11	6.31	78.7	11.52
KL (mm)	5.62	3.72-6.97	11.80	11.21	90.3	21.96
KB (mm)	1.99	1.57-2.66	12.59	11.03	76.8	19.91
L/B	2.83	1.99-3.64	13.02	11.41	76.8	20.59
KLAC (mm)	8.88	5.65-12.18	15.54	13.99	81.1	25.95
ER	1.62	1.21-2.06	12.39	10.32	69.4	17.70
WU (ml)	199.26	90.0-347.5	28.97	26.28	82.3	49.12
VER	4.19	2.90-4.80	15.92	12.62	62.8	20.61
AC (%)	24.19	19.36-26.65	7.53	5.64	56.1	8.69
Grain yield/plant (g)	17.85	8.96-28.27	27.04	26.18	93.8	52.23

Significant at 5% level   Significant at 1% level

DFF: Days to 50% Flowering; PH: Plant Height; EBT: Ear Bearing Tillers; PL: Panicle Length;TW: Test Weight; HRR:Head Rice Recovery; KL: Kernel Length; KB: Kernel Breadth;L/B: Length/Breadth Ratio; KLAC: Kernel Length after Cooking; ER: Elongation Ratio; WU: Water Uptake; VER: Volume Expansion Ratio; AC: Amylose Content

Table 2: Genotypic correlation coefficients of grain yield with yield components and quality parameters in rice

Character	DFF	PH	EBT	PL	TW	HRR	KL	KB	L/B	KLAC	ER	WU	VER	AC	GY
DFF	1.000	0.2709*	0.473**	0.132	-0.0530	0.1361	-0.4191**	-0.0008	-0.4086**	-0.2110	0.1704	0.1970	0.0055	0.2273	0.3254*
PH		1.000	-0.118	0.299*	-0.0569	-0.3114*	-0.2144	0.0558**	-0.2396	-0.2495*	-0.1243	0.0918	0.0552	-0.0518	-0.0953
EBT			1.000	0.553**	-0.2926*	0.4137**	-0.3185*	-0.4009**	-0.0101	-0.2036	0.1566	0.0481	0.4633**	-0.0823	0.7970**
PL				1.000	-0.1369	0.5146**	-0.3886**	-0.1113	-0.3012*	-0.2106	0.0242	0.2662*	0.0777	-0.5109**	0.4679**
TW					1.000	-0.1687	0.5181**	0.6785**	-0.0599	0.4634**	-0.0097	0.1216	-0.1729	0.4305**	-0.3540*
HRR						1.000	-0.2601*	-0.2338	-0.1020	0.1522	0.4933**	0.1333	0.3340**	-0.1090	0.5195**
KL							1.000	-0.4090**	0.6224**	0.6514**	-0.1765	0.1025	-0.1331	0.0862	-0.2944*
KB								1.000	-0.4582**	0.3297**	-0.0380	0.1824	-0.3805**	0.3854**	-0.3755**
L/B									1.000	0.3319**	0.1648	-0.0313	0.1666	-0.2619*	-0.0093
KLAC										1.000	0.5117**	0.1484	0.2273	0.0035	-0.0272
ER											1.000	0.0264*	0.5217**	-0.0697	0.3026*
WU												1.000	0.0082	0.2246	0.2253
VER													1.000	-0.4775**	0.4991**
AC														1.000	-0.1852

* Significant at 5% level ** Significant at 1% level

DFF: Days to 50% Flowering; PH: Plant Height; EBT: Ear Bearing Tillers; PL: Panicle Length; TW: Test Weight; HRR:Head Rice Recovery; KL: Kernel Length; KB: Kernel Breadth; L/B: Length/Breadth ratio; KLAC: Kernel Length After Cooking; ER: Elongation Ratio; WU: Water Uptake; VER: Volume Expansion Ratio; AC: Amylose Content

Table 3: Path coefficient analysis of grain yield with yield components and quality parameters in rice genotypes

Character	DFF	PH	EBT	PL	TW	HRR	KL	KB	L/B	KLAC	ER	WU	VER	AC
DFF	**0.0023**	0.0006	0.0011	0.0003	-0.0001	0.0003	0.0010	0.000	-0.0010	-0.0005	-0.0004	0.0005	0.0000	0.0005
PH	-0.0144	**-0.0533**	0.0063	-0.0159	0.0030	0.0166	0.0114	-0.0030	0.0128	0.0133	0.0066	-0.0049	-0.0029	0.0028
EBT	0.2689	-0.0669	**0.5687**	0.3147	-0.1664	0.2353	-0.1811	-0.2280	-0.0057	-0.1158	0.0891	0.0274	0.2635	-0.0468
PL	0.0188	0.0426	0.0790	**0.1428**	-0.0195	0.0735	-0.0555	-0.0159	-0.0430	-0.0301	0.0035	0.0380	0.0111	-0.0729
TW	0.0161	0.0173	0.0888	0.0416	**-0.3035**	0.0512	-0.1573	-0.2060	0.0182	-0.1407	0.0029	-0.0369	0.0525	-0.1307
HRR	0.0095	-0.0216	0.0288	0.0358	-0.0117	**0.0695**	-0.0181	-0.0163	-0.0071	0.0106	0.0343	0.0093	0.0232	-0.0076
KL	0.1377	0.0704	0.1046	0.1277	-0.1702	0.0854	**-0.3285**	-0.1343	-0.2044	-0.2140	0.0580	-0.0337	0.0437	-0.0283
KB	-0.0002	0.0157	-0.1126	-0.0313	0.1906	-0.0657	0.1149	**0.2809**	-0.1287	0.0926	-0.0107	0.0512	-0.1069	0.1083
L/B	-0.1099	-0.0644	-0.0027	-0.0810	-0.0161	-0.0274	0.1674	-0.1232	**0.2689**	0.0893	-0.0443	-0.0084	0.0448	-0.0704
KLAC	-0.0482	-0.0570	-0.0465	-0.0481	0.1059	0.0348	0.1489	0.0754	0.0759	**0.2286**	0.1170	0.0339	0.0519	0.0008
ER	-0.0081	0.0059	-0.0075	-0.0012	0.0005	-0.0236	0.0084	0.0018	0.0079	-0.0244	**-0.0477**	0.0013	-0.0249	0.0033
WU	0.0232	0.0108	0.0057	0.0313	0.0143	0.0157	0.0121	0.0215	-0.0037	0.0175	-0.0031	**0.1177**	0.0010	0.0264
VER	0.0011	0.0112	0.0937	0.0157	-0.0350	0.0676	-0.0269	-0.0770	0.0337	0.0460	0.1055	0.0017	**0.2023**	-0.0966
AC	0.0287	-0.0065	-0.0101	-0.0644	0.0543	-0.0137	0.0109	0.0486	-0.0330	0.0004	-0.0088	0.0283	-0.0602	**0.1260**

DFF: Days to 50% Flowering; PH: Plant Height; EBT: Ear Bearing Tillers; PL: Panicle Length;TW: Test Weight; HRR:Head Rice Recovery; KL: Kernel Length; KB: Kernel Breadth;L/B: Length/Breadth Ratio;KLAC: Kernel Length After Cooking; ER: Elongation Ratio; WU: Water Uptake; VER: Volume Expansion Ratio; AC: Amylose Content.

The values in **bold** and diagnolly represented are direct effects and all others are indirect effects.

Genetic variability, Correlation and Path Analysis for Quantitative Characters in Rainfed Upland Rice of Uttarakhand Hills

J. P. Aditya* and Anuradha Bhartiya

Crop Improvement Division, Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR), Almora 263 601 Uttarakhand.

Abstract

Genetic parameter, correlation coefficients among yield and yield components, direct and indirect effect of yield components on yield were studied in eighteen rice genotypes under rainfed ecosystem for fifteen quantitative traits. The analysis of variance revealed that there were highly significant differences for all the characters among the genotypes. The estimate of GCV and PCV was found to be highest for grain yield per plot followed by fertile grains per panicle and grains per panicle. The broad sense heritability was highest for plant height and fertile grains per panicle (98.14%) followed by grains per panicle (97.74%), days to 50 per cent flowering (95.18) and days to maturity (94.71). The estimate of genetic advance was found to be highest for grains per panicle and fertile grains per panicle. The number of grains per panicle and fertile grains per panicle had high heritability as well as high genetic advance. The phenotypic correlation coefficient among fifteen traits showed that grain yield was significantly and positively correlated with plant height, days to 50 per cent flowering, days to maturity, flag leaf length, flag leaf width, panicle length, grains per panicle, fertile grains per panicle, kernel length and L/B ratio. The estimates of direct and indirect effect revealed that L/B ratio had the highest positive direct effect on grain yield followed by kernel width, grains per panicle, and tillers per plant.

*Corresponding author : jayprakashaditya@gmail.com

Key Words: Rainfed upland rice, genetic parameters, correlation, path analysis, yield components

Rice (*Oryza sativa* L.) is the staple food of more than three billion people in the world. Nearly, hundred million people depend on the upland rice as their daily staple food. Almost two third of the upland rice area is in Asia. In India, the total area under upland rice is 6 m. ha. which accounts 13 per cent of the total area under rice crop in the country. Upland rice is generally grown under rainfed conditions and crop growth is entirely depends on the monsoon. Upland rice ecology is much harsh environment for rice production in which intermittent drought is the major constraint (Hanamaratti *et al*., 2005) and cause a yield penalty from 12 to 46 per cent (Oak *et al*., 2006). Rainfed upland rice is an important component of cropping system in Uttarakhand hills. Rainfed upland rice cultivation in hills is suffering from the problem of poor productivity mainly due to erratic rainfall, poor soil fertility as well as lack of improved varieties. Poor yield potential of traditional rice cultivars necessitates the development of the high yielding cultivars for rainfed upland condition of hills. Development of high yielding varieties requires a thorough understanding of existing genetic variability as well as magnitude and direction of genetic association among the yield contributing characters. Knowledge of association direct and indirect effect between grain yield and other characters can be helpful in efficient selection of suitable cultivars of rice for rainfed upland condition. Therefore, the present study aimed to determine the extent of genetic variability, genetic parameters with correlation and path coefficient to select superior rice genotypes adapted to rainfed upland ecosystem of Uttarakhand hills.

Materials and Methods

The experimental material consisted of eighteen rainfed upland rice genotypes (Table 1). These genotypes were evaluated in a completely randomized block design with three replications during *kharif* season at experimental farm of Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR), Almora. The crop was direct seeded under the rainfed condition. Each plot consisted of five rows plot of 3.5m length with spacing of 20cm between rows. Ten plants from middle row of each entry in each replication were randomly selected for recording observations on quantitative traits *viz.*, plant height, tillers per plant, flag leaf length, flag leaf width, panicles per plant, panicle length, grains per panicle, fertile grain per panicle, thousand grain weight, kernel length, kernel width and L/B ratio. Whereas, days to 50 per cent flowering, days to maturity and grain yield were recorded on whole plot basis. The mean value was used as the replicated data and was subjected to statistical analysis using INDOSTAT software package. Analysis of variance was estimated following Panse and Sukhatme (1985). The phenotypic and genotypic coefficient of variability, heritability in broad sense, genetic advance at 5 per cent selection intensity were computed as suggested by Johnson *et al.* (1955). The phenotypic correlation coefficients among all the traits under study were calculated following Al-Jobouri *et al.* (1958) and the path analysis was carried out as per method of Dewey and Lu (1959).

Results and Discussion

Analysis of variance indicated the existence of highly significant differences among the genotypes for all the characters studied except tillers per plant. This suggested that there is an inherent genetic difference among the genotypes (Table 2). The range, mean, standard error of mean, genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance at 5 per cent selection intensity for different characters are given in Table-3. Among rainfed upland rice genotypes, the average grain yield per plot ranged from 0.23 kg to 0.95 kg and crop duration varied from 114 to 131 days. Five genotypes *viz.*, VL 8204 (0.95 kg/plot), VL 8302 (0.82 kg/plot), VL 8185 (0.80 kg/plot), VL 31402 (0.75 kg/plot) and VL 8292 (0.70 kg/plot) were found significantly superior for grain yield. A wide range of variability was observed for grains per panicle (76-150) followed by fertile grain per panicle (65-137). The range of variation obtained for kernel width (2.22-2.63) and flag leaf width (1.39-1.95) was least when compared to all other characters. The estimate of GCV and PCV was found to be highest for yield per plot followed by fertile grains per panicle and grains per panicle. Padmaja *et al.* (2008) also recorded similar observation for grains per panicle and single plant yield. Low GCV and PCV estimates were noticed for plant height, days to 50 per cent flowering, days to maturity, tillers per plant, panicle length, thousand grain weight, kernel length, kernel width and LB ratio. These results are in conformity with Padmaja *et al.* (2008) for days to 50 per cent flowering and panicle length. The estimates of PCV were slightly higher than the corresponding GCV estimates for plant height, days to 50 per cent flowering, days to maturity, grains per panicle and fertile grains per panicle indicating that the characters were less influenced by the environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits. In general, the magnitude of PCV was found to be higher than the corresponding GCV for all the characters suggesting the influence of environment on the expression of the traits. However, the differences between PCV and GCV were very small for most of the characters indicating the lesser contribution of environmental variation towards the expression of these traits. Similar observations were also recorded by (Karad and Pol 2008; Ubarhande *et al.*, 2009) in rice genotypes.

The broad sense heritability was highest for plant height and fertile grains per panicle (98.14%) followed by grains per panicle (97.74%), days to 50 per cent flowering (95.18) and days to maturity (94.71). Sharma and Sharma (2007) also reported similar finding for these traits. The estimate of heritability alone is not very much useful because it includes the effect of both additive and non additive gene. The genetic advance is a useful indicator of the progress that can be expected as a result of exercising selection on the pertinent population. The estimate of genetic advance was found to be highest for grains per panicle and fertile grains per panicle (Sharma and Sharma, 2007). The number of grains per panicle and fertile grains per panicle had high heritability as well as high genetic advance. It is suggested that these characters were predominantly controlled by additive gene action. Hence genetic improvement through selection for these traits may be effective. Heritability estimates along with genetic advance are more helpful in predicting gain under selection than heritability estimate alone (Sinha *et al.*, 2004; Johnson *et al.*, 1955).

The phenotypic correlation coefficient among 15 traits including grain yield in the present investigation is presented in Table-4. Grain yield was observed to be positively and significantly correlated with plant height, days to 50 per cent flowering, days to maturity, flag leaf length, flag leaf width, panicle length, grains per panicle, fertile grains per panicle, kernel length and L/B ratio. Among the component traits plant height was significantly positively correlation with days to 50 per cent flowering, days to maturity, flag leaf length, flag leaf width, panicle length, grains per panicle and fertile grains per panicle. Sharma and Sharma (2009); Subudhi and Dikshit (2009) reported significant positive correlation between plant height and grains per panicle and panicle length. Days to 50 per cent flowering showed significant positive correlation with days to maturity, flag leaf length, flag leaf width, panicle length, grains per panicle and fertile grains per panicle. Chandra *et al*. (2006) reported significant positive correlation of days to 50 per cent flowering with panicle length. Days to maturity was found to be significantly positively correlated with flag leaf length, flag leaf width, panicle length, grains per panicle and fertile grains per panicle. Tillers per plant exhibited significant positive correlation with panicles per plant while it was negatively correlated with panicle length. Flag leaf length, flag leaf width, panicle length, grains per panicle and fertile grains per panicle were mutually correlated with each other. L/B ratio showed significant positive correlation with grains per panicle, thousand grain weight, kernel length and kernel width.

The above inter se association amongst the traits indicated that although tillers per plant, panicles per plant, thousand grain weight, and kernel width did not exhibit positive significant association with grain yield, their role in contributing towards grain yield could not be overlooked as these component traits exhibited positively significant association with important yield attributes. Thus, these traits may be assumed to indirectly contribute via other traits in governing grain yield. In this regard it is important to partition out the observed phenotypic association into direct and indirect effects of the component traits towards grain yield.

A character contributing to grain yield may contribute directly or indirectly. It is essential to conduct the path analysis. The estimates of direct and indirect effect are presented in Table-5. In the present investigation, L/B ratio had the highest positive direct effect on grain yield followed by kernel width, grains per panicle, and tillers per plant. Highest positive but indirect effect was observed for kernel length via L/B ratio followed by thousand grain weight via L/B ratio. Plant height, days to 50 per cent flowering, days to maturity, tillers per plant, flag leaf length, panicles per plant, thousand grains weigh and kernel length grains per panicle were observed to contribute positively to an appreciable extent via L/B ratio. Direct and indirect effect of yield component traits on grain yield have also been reported earlier (Shivani and Reddy, 2000; Kavitha and Reddi, 2001; Biao *et. al.,* 2002; Shanthala *et al.,* 2004 and Shashidhar *et al.,* 2005).

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Table 1. List of rainfed upland rice genotypes under study and their pedigree

Genotypes	Pedigree
VL 8257	Pant Dhan 6 x Barakat
VL 8201	VR 539-2 x VLD 81
VL 8204	VR 539-2 x VLD 81
VL 8302	VL 9588 x A-57
VL 8292	VL 9588 x A-57
VL 8214	VLD 81 x VR 539-2
VL 8188	VR 539-2 x IR 63872-93-2-37
VL 8185	VR 539-2 x IR 63872-93-2-37
VL 8369	VL 9588 x VR 539-2
VL 31384	China 4 x BG 367-4
VL 31402	SRSN 38 x VL 6394
VL 31430	Pant Dhan 6 x VL 3288
VL 31590	VL 3861 x IR 59656-5- K-1
VL 31567	Vivek Dhan 82 x WAB 337-B-B-13-1-1-3
VL 31440	VHC 1253 x Thapachini
VL 31419	Vivek Dhan 82 x VLD 206
Vivek Dhan 154	VL Dhan 221 x VL- 24
VLD 221	IR 2053-521-1-1-1 x Ch- 1039

Table 2: Analysis of variance for various yield contributing characters

Source of variance	d.f	Plant height	Days to 50% flowering	Days to maturity	Tillers per plant	Flag leaf length	Flag leaf width	Panicles per plant	Panicle length	Grains per panicle	Fertile grains per panicle	1000grain weight	Grain yield per plot	Kernel length	Kernel width	L/B ratio
Replication	2	18.91	0.91	4.24	0.91	1.27	0.01	1.46	1.04	16.07	4.46	1.13	0.009	0.07	0.006	0.0004
Treatments	17	281.62**	74.73**	70.01**	0.90	40.50**	0.08**	1.09*	5.39**	1898.27**	1589.33**	17.68**	0.12**	0.47**	0.04**	0.61**
Error	34	1.77	1.24	1.28	0.71	1.91	0.008	0.54	0.60	14.54	9.95	1.32	0.004	0.03	0.004	0.01

*, ** Significant at 5% and 1% level of probability respectively.

Table 3: Range, mean and genetic parameters of 15 yield attributing characters in rainfed upland rice

Characters	Range	GM	CV %	CD at 5%	SEm	GCV (%)	PCV (%)	h^2 (%)	GA at 5%	GA as % mean
Plant height (cm)	104-142	121.52	1.09	2.21	1.08	7.95	8.02	98.14	19.71	16.22
Days to 50% flowering (days)	82-99	91.74	1.21	1.85	0.91	5.39	5.53	95.18	9.95	10.84
Days to maturity (days)	114-131	122.81	0.92	1.88	0.92	3.90	4.00	94.71	9.60	7.81
Tillers per plant (number)	5-8	6.30	13.39	1.40	0.69	3.96	13.96	8.03	0.14	2.31
Flag leaf length (cm)	21.29-34.31	28.85	4.78	2.29	1.13	12.43	13.32	87.09	6.90	23.90
Flag leaf width (cm)	1.39-1.95	1.66	5.44	0.15	0.07	9.00	10.51	73.21	0.26	15.86
Panicles per plant (number)	5-7	5.96	12.34	1.22	0.60	7.20	14.28	25.38	0.45	7.47
Panicle length (cm)	20.98-26.13	22.98	3.37	1.29	0.63	5.49	6.45	72.61	2.22	9.65
Grains per panicle (number)	76-150	118.43	3.22	6.33	3.11	21.16	21.40	97.74	51.03	43.09
Fertile grains per panicle (number)	65-137	103.76	3.04	5.23	2.58	22.10	22.31	98.14	46.80	45.10
1000grain weight (g)	22.53-31.22	27.64	4.16	1.91	0.94	8.45	9.42	80.52	4.32	15.62
Grain yield per plot (Kg)	0.23-0.95	0.55	12.07	0.11	0.05	35.72	37.70	89.74	0.38	69.70
Kernel length (cm)	5.88-7.35	6.68	2.37	0.26	0.13	5.74	6.21	85.48	0.73	10.94
Kernel width (cm)	2.22-2.63	2.47	2.63	0.11	0.05	4.44	5.16	74.03	0.19	7.86
L/B ratio	2.40-3.24	2.72	3.74	0.17	0.08	9.41	10.13	86.35	0.49	18.01

Table 4: Phenotypic correlation coefficients among grain yield and component traits in rainfed upland rice

Characters	Plant height	Days to 50% flowering	Days to maturity	Tillers per plant	Flag leaf length	Flag leaf width	Panicles per plant	Panicle length	Grains per panicle	Fertile grains per panicle	1000grain weight	Grain yield per plot	Kernel length	Kernel width	L/B ratio
Plant height	1.000	0.645**	0.691**	-0.241	0.708 **	0.418**	-0.126	0.499**	0.308 *	0.335*	0.164	0.471**	0.109	-0.118	0.134
Days to 50% flowering		1.000	0.980**	-0.154	0.4453**	0.477**	-0.083	0.408**	0.315 *	0.306*	0.162	0.284*	0.033	-0.139	0.107
Days to maturity			1.000	-0.171	0.459**	0.499**	-0.084	0.436**	0.313*	0.303*	0.139	0.307*	0.023	-0.126	0.095
Tillers per plant				1.00	-0.105	-0.0918	0.849**	-0.317 *	-0.226	-0.240	0.006	0.053	0.147	-0.164	0.181
Flag leaf length					1.000	0.663**	-0.027	0.4170**	0.583**	0.602**	0.313*	0.602**	0.202	-0.036	0.133
Flag leaf width						1.000	-0.039	0.369 **	0.535**	0.515**	0.057	0.383**	-0.134	0.157	-0.186
Panicles per plant							1.000	0.394**	-0.256	0.279*	0.112	-0.042	0.238	-0.206	0.259
Panicle length								1.000	0.543**	0.545**	-0.057	0.369**	-0.254	0.163	-0.251
Grains per panicle									1.000	0.982**	0.122	0.485**	-0.156	0.329*	0.289*
Fertile grains per panicle										1.000	0.133	0.502**	-0.099	0.294*	-0.236
1000grain weight											1.000	0.184	0.688**	0.089	0.390 **
Grain yield per plot												1.000	0.306*	-0.256	0.319 *
Kernel length													1.000	0.479**	0.884**
Kernel width														1.000	0.832**
L/B ratio															1.000

Table 5: Phenotypic path coefficient analysis among the quantitative characters in rainfed upland rice

Characters	Plant height	Days to 50% flowering	Days to maturity	Tillers per plant	Flag leaf length	Flag leaf width	Panicles per plant	Panicle length	Grains per panicle	Fertile grains per panicle	1000grain weight	Kernel length	Kernel width	L/B ratio	Grain yield per plot
Plant height	**0.330**	0.213	0.228	-0.080	0.234	0.138	-0.042	0.164	0.101	0.110	0.054	0.036	-0.039	0.044	0.471
Days to 50% flowering	-0.295	**-0.457**	-0.448	0.071	-0.203	-0.218	0.038	-0.186	-0.144	-0.140	-0.074	-0.015	0.064	-0.049	0.284
Days to maturity	0.130	0.184	**0.188**	-0.032	0.086	0.094	-0.016	0.082	0.059	0.057	0.026	0.004	-0.024	0.018	0.307
Tillers per plant	-0.129	-0.082	-0.091	**0.532**	-0.056	-0.049	0.452	-0.169	-0.120	-0.128	0.003	0.078	-0.087	0.096	0.053
Flag leaf length	0.039	0.025	0.026	-0.006	**0.056**	0.037	-0.002	0.023	0.032	0.033	0.017	0.011	-0.002	0.007	0.602
Flag leaf width	0.092	0.105	0.110	-0.020	0.146	**0.220**	-0.009	0.081	0.118	0.113	0.013	-0.029	0.034	-0.041	0.383
Panicles per plant	0.058	0.038	0.038	-0.389	0.012	0.018	**-0.458**	0.180	0.117	0.128	-0.051	-0.109	0.094	-0.119	-0.042
Panicle length	0.041	0.033	0.036	-0.026	0.034	0.030	-0.032	**0.082**	0.044	0.045	-0.005	-0.021	0.013	-0.021	0.369
Grains per panicle	0.253	0.258	0.257	-0.185	0.478	0.439	-0.210	0.446	**0.821**	0.806	0.100	-0.128	0.270	-0.237	0.485
Fertile grains per panicle	-0.114	-0.104	-0.103	0.082	-0.205	-0.175	0.095	-0.186	-0.334	**-0.341**	-0.045	0.034	-0.100	0.080	0.502
1000grain weight	-0.015	-0.015	-0.013	-0.001	-0.029	-0.005	-0.010	0.005	-0.011	-0.012	**-0.093**	-0.064	-0.008	-0.036	0.184
Kernel length	-0.141	-0.043	-0.030	-0.189	-0.261	0.173	-0.306	0.327	0.202	0.128	-0.888	**-1.290**	0.618	-1.140	0.306
Kernel width	-0.130	-0.153	-0.139	-0.180	-0.040	0.173	-0.227	0.180	0.362	0.323	0.099	-0.528	**1.102**	-0.917	-0.256
L/B ratio	0.353	0.283	0.249	0.475	0.350	-0.490	0.684	-0.661	-0.762	-0.620	1.028	2.327	-2.191	**2.633**	0.319

Residual effect= 0.591

Study on Grain and Water Productivity of Rice-Zero-Till Maize Cropping System

D. Sreelatha*, M. Srinivasa Raju, M. Devender Reddy, G. Jayasree and D. Vishnu Vardhan Reddy

Acharya N.G.Ranga Agricultural University, Rajendranagar, Hyderabad, Andhra Pradesh

Abstract

The effect of two rice crop establishment methods (transplanted and aerobic), two irrigation (IW: CPE ratio of 0.8 and 1.0) and four phosphorus levels (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) on rice-zero-tillage maize cropping system is studied during 2007-08 and 2008-09 at a field experiment station at Hyderabad. Transplanted rice on an average gave 1.02 t ha^{-1} higher yield than aerobic rice (4.49 t ha^{-1}). However, succeeding maize grown as zero-tilled crop after aerobic rice has 0.34 t ha^{-1} more yields than that after transplanted rice (6.34 t ha^{-1}). The higher water productivity of aerobic rice (0.395 kg m^{-3}) and succeeding zero-tilled maize (1.17) as compared to transplanted rice and succeeding maize (0.37 and 1.095 kg m^{-3}) together brought higher water productivity (0.64 kg m^{-3}) in aerobic rice-maize system in comparison to transplanted rice-maize (0.54 kg m^{-3}). With increase in level of irrigation from 0.8 to 1.0 IW: CPE ratio and increase in P dose, the consumptive use of water by maize increased during both the years of study.

Key words: Rice, zero-till maize, grain yield, consumptive use, water productivity

Rice (*Oryza sativa* L.)-Maize (*Zea mays* L.) is one of the pre-dominant cropping system of both command and non-command areas of Andhra Pradesh. Shortage of irrigation water and increased cost of transplanting in rice made several researchers to study the possibility of rice cultivation under irrigated dry conditions (aerobic). The early crop maturity (7-10 days) and ease of establishment of succeeding crop after aerobic rice cultivation are additional benefits. The concept of zero-tillage is gaining momentum in traditional areas under rice-maize sequence. This technique aids in overcoming planting difficulties in rice fallow, reduces weeds and improves fertilizers and water use efficiency and reduce cost of cultivation (DMR Technical Bulletin, 2009).

*Corresponding author: lathadogga@gmail.com

Irrigation as well as nutritional requirements, particularly, the phosphorus (P) of zero-till maize is different from conventionally sown maize because of alteration of physico-chemical properties of soil under rice-based situations. Maize uses water efficiently in terms of total dry matter production among the cereals. Frequency and depth of irrigation has pronounced effect on grain yield of maize. Positive relationship between irrigation and 'P' response in many field crops particularly in maize have been indicated mainly due to the fact that 'P' availability of both soil and applied increases due to adequacy of soil water. Keeping above aspects in view, a study was under taken to assess zero-tillage maize performance under different irrigation and P fertilization following a aerobic and transplanted crop.

Material and Methods

The field study was conducted during rainy and winter seasons of 2007-08 and 2008-09 at Water Technology Centre, Agricultural College Farm, Rajendranagar ($78^0$23 E and $17^0$1 N and 524.6 m above MSL), Hyderabad, Andhra Pradesh. The location with semi arid tropical climate is characterized by hot summer and cold winters. The mean maximum and minimum temperatures ranges from 31.2^0C and 15.6^0C in 2007-08 and 32.1^0C and17.0^0C in 2008-09 had annual rainfall of 398.5 mm and 1095.6 in 2007-08 and 2008-09 which was received in 38 and 39 rainy days. The experimental soil was sandy clay loam with pH 7.4, low in organic carbon (0.51%) and available nitrogen (240.6 kg ha^{-1}), medium in available phosphorus (15.39 kg ha^{-1}) and high in available potassium (631.6 kg ha^{-1}). The experiment was conducted in split-plot design with four replications. During rainy season, two methods of rice crop establishment (transplanted and aerobic) were evaluated whereas in winter season zero-tilled maize was grown in sequence to rice while considering the two previous rice crop establishment methods as main-plot and combination of two levels of irrigation (1.0 and 0.8 Irrigation Water (IW): Cumulative Pan Evaporation (CPE) and four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) as sub-plot treatments. During rainy season semi dwarf rice variety (MTU 1010) was transplanted at a spacing of 20 x 15 cm in a puddled field. Whereas under aerobic method, direct seeding of dry seed was done in solid rows at row spacing of 20 cm. Nursery sowing was done for transplanted rice on the same day as of Aerobic Rice (AR) sowing. A fertilizer dose of 120-60-40 kg, N-P_2O_5- K_2O ha^{-1} in the form of urea, Single Super Phosphate (SSP) and Muriate Of Potash (MOP) was applied. In AR, weeds were controlled by spraying pendimethalin 35 EC @ 1.0 kg ha^{-1} in 500 l of water after 24 hours of seeding followed by push hoeing at 25 and 45 days after sowing. In transplanted rice, butachlor 50 EC @1.25 kg ha^{-1} mixed with sand was applied at 2 Days After Transplanting (DAT) maintaining thin film of water followed by one hand weeding at 30 DAT. Two sprays of 0.2% ferrous ammonium sulphate solution were also given at weekly interval for AR to correct the iron deficiency.

For transplanted rice, 2 cm standing water was maintained upto panicle initiation stage and later 5 cm of level was maintained. In AR a soaking irrigation was given initially later on from 7 days onwards irrigations (5 cm) were given when the soil moisture reached to 28% corresponding to -20 Kpa tension that was measured with theta probe soil moisture sensor ML2. The amount of water applied was measured through water meter and was directly delivered to plot. During winter season, paraquat 50 EC @ 1.25 kg ha^{-1} was sprayed immediately after rice harvest to control the existing weeds as well as to arrest the re growth of rice stubbles. Maize hybrid 'DHM 117' seeds were dibbled at a spacing of 60 x 20 cm under zero-tillage and a day later atrazine @1.0 kg ha^{-1} was sprayed for weed control. A uniform fertilizer dose of120-40 kg N-K_2O ha^{-1} fertilizers along with P fertilizer as per the treatment was applied. The entire P and K was applied as basal in the form of SSP and MOP and N was applied in three equal splits (basal, knee high and tasseling & silking) in the form of urea. Pests and disease control were adopted as per the recommendations for the region. One pre-sowing irrigation followed by one common irrigation each of 2.5 cm immediately after sowing of the crop was given to ensure uniform germination. Subsequent irrigations were scheduled based on IW: CPE ratio. In IW: CPE approach, 5 cm depth of irrigation water was applied uniformly when CPE reached 6.25 and 5.0 cm in order to get a ratio of 0.8 and 1.0. CPE values were obtained from standard USWB Class A pan. The soil moisture depletion method was employed to determine the Consumptive Use (CU). Consumptive use was calculated from change in the soil moisture content in successive samples Sankara Reddi and Yellamanda Reddy, 1995).

$$U = \sum^{n} (Mxi - Mzi)$$

i=1 --------------------- x BDi x Di

100

Where, U = Consumptive use or actual moisture used from the root zone within one irrigation cycle (mm)

n = Number of soil layers sampled in the root zone depth D

Mxi = Soil moisture percentage at the time of first sampling in the i^{th} layer

Mzi = Soil moisture percentage at the time of second sampling in the i^{th}layer

BDi =Bulk density of the soil of i^{th} layer (g cm^{-3})

Di = Depth of ith layer of the soil (mm)

CU = ∑ U

The seasonal CU was obtained by adding CU values for each sampling interval. Soil moisture extraction was worked out for different soil depths for the period of sampling interval during the crop growth. Then, the total moisture extracted (SMDt) from the root zone depth (0-60 cm) was calculated using the expression

SMDt = SMD 1 + SMD2 + SMD3 + SMD4

where, SMDt = Soil moisture depleted from 0-60 cm

$SMD_{1,2,3,4}$ = Soil moisture depleted from 0-15,15-30, 30-45 and 45-60 cm

Moisture depletion from each part of the soil depth was then expressed as percentage of total moisture depletion from the part of soil depth. A comprehensive analysis of water productivity **(**kg m^{-3}**)** was done. Crop water productivity was estimated as ratio of maize yield (kg) to that of CU (m^3) of the crop and field water productivity (kg m^{-3}) was calculated as ratio of yield (kg) to that of water applied to the crop including rainfall (m^3) in the season.

Results and Discussion

Crop establishment methods and yield

Transplanted rice rerecorded 1.09 tonne higher yield than aerobic crop (4.63 and 4.35 tonne ha^{-1} in 2007 and 2008). The higher grain yield might be due to efficient utilization of water and nutrients by puddle transplanted rice resulting in yield attributes. The low yields in aerobic rice may be due to excessive vegetative growth and more panicle density that caused tiller mortality and spike let sterility as compared to transplanted rice. Similar results are also reported by Gill *et al*. (2006).

Winter maize productivity grown under zero-tilled conditions after aerobic rice was higher than that after transplanted rice (Table 1) on account of greater values of yield attributes (cob number ha^{-1}, cob weight, cob length, cob girth, number of grains cob^{-1} and shelling percentage). The favorable conditions under AR cultivation might have improved the plant growth and dry matter and also crop with optimum source-sink ratio facilitate proper portioning of photo synthetates and thus resulted in better filling of grains. In case of transplanted method of establishment, due to puddling soil structural changes along with formation of hard pan development in sub-soil might have restricted the root growth which in turn reduced shoot growth. Whereas in, aerobic rice the dry land preparation was done and good pulverized soil condition facilitated for better root development and good crop performance. These results are supported by Gangwar *et al*. (2008). The interaction between methods of crop establishment and irrigation level indicated that maize grain yield with 1.0 IW: CPE ratio irrigation was significantly higher than 0.8 IW:CPE ratio after both the methods of crop establishment. Maximum benefit from irrigation was realized under aerobic method of cultivation in both years (Table 1). The interaction between irrigation and P level also attained level of significance. Application of 30 kg P_2O_5 ha^{-1} at irrigation of 1.0 IW:CPE ratio resulted in comparable grain yield of maize as that of 90 kg P_2O_5 ha^{-1} at irrigation level of 0.8 IW:CPE ratio. The beneficial effect of P application was more pronounced at IW: CPE ratio of 1.0 than 0.8 at all P levels (Table 2).

Crop establishment methods - water use and water productivity

In the present study, transplanted method recorded the highest field water use compared to AR. It was observed that on an average AR recorded a saving of 35.7% and 29.2% of field water compared to transplanted rice in 2007 and 2008 (Table 3). LavBhushan *et al*. (2007) observed 23% saving of irrigation water with direct seeded rice over transplanted rice. The effective rainfall during 2008 (5795 m^3 ha^{-1}) was much higher than that in 2007 (2238 m^3 ha^{-1}) and thus the water applied through irrigation during 2008 was comparatively lower than 2007. Therefore, the total water use was higher during 2008 than 2007. Field water productivity was lower in 2008 irrespective of establishment method because of lower grain yield. In AR the field water use was low as compared to transplanted rice because of dry land preparation which led to reduction in irrigation water and total water requirement. Similar findings were also reported by Cabangon *et al*. (2000) and Tabbal *et al*. (2000). Lower water consumption by AR has resulted in higher water productivity (0.40 and 0.34 kg m^3 in 2007 and 2008) as compared to the transplanted method of cultivation (0.44 and 0.35 kg m^3 in 2007 and 2008 respectively) (Table 3). In AR, seepage and percolation and evaporation losses are greatly reduced and also increased effective utilization of rain water which helped in enhancing the water productivity (Singh and Vishwanathan, 2006; Bouman *et al*., 2005; Gill *et al*., 2006).

In zero-tillage maize, both the methods of rice establishment utilized more or less same field water under different irrigation schedules during two years of study (Table 4). Irrigation scheduled at 1.0 IW : CPE ratio has recorded more field water use due to more number of irrigations than 0.8 ratio. The field water productivity was higher in the latter irrigation schedule than that in the former. The CU of maize after transplanted rice was less (343.8 and 362.5 mm) as compared to AR (382.8 and 396.2 mm) in both years and water productivity of maize was found to be more when grown after transplanted rice than after over aerobic rice. In maize grown after puddle rice, the leaching losses are minimum where as after aerobic rice relatively leaching of irrigation water is more due to un-puddled condition.With increase in level of irrigation from 0.8 to 1.0 IW : CPE ratio there was an increase in CU of water by maize during both the years of study. During 2008-09, maximum CU was recorded due to more number of irrigations provided to the maize crop. Similar results of maximum water requirement (58.86 cm) was recorded under IW:CPE of 1.2 and minimum water requirement (44.98 cm) was observed with 0.6 IW:CPE ratio was reported by Bharathi *et al*.(2007).The system water use was lowest in aerobic rice-maize system and thus system water productivity was higher as compared to transplanted rice-maize during the years of study (Table 4).

Increase in level of P application resulted in increase in CU (Table 5). With each level of P increase from 0 to 90 kg P_2O_5 ha^{-1} the CU use increased considerably. The difference in CU between control and 90 kg P_2O_5 ha^{-1} was 68.8 and 74.6 mm during 2007-08 and 2008-09 respectively.

The influence of irrigation frequencies are more pronounced on CU use rather than on water productivity. The luxuriant crop growth at 1.0 IW: CPE which utilized more irrigation water to meet the higher crop demand and realized higher productivity. The water productivity was higher in maize grown after transplanted than aerobic rice. Irrigation at IW:CPE ratio of 0.8 recorded higher water productivity than irrigation at IW : CPE ratio of 1.0.

Increase in the level of P increased the water productivity. The increase in water productivity with increase in level of P was noticed up to 30 kg P_2O_5 ha^{-1} during 2007-08 and upto 60 kg P_2O_5 ha^{-1} during 2008-09.

Soil moisture extraction pattern

Based on the CU of water, soil moisture extraction pattern was maximum from the top 0-15 cm soil and decreased with each successive soil layers irrespective of preceding rice establishment methods, levels of irrigation and phosphorus. Lowest extraction was observed from 45-60 cm soil depth (Table 6). Slightly more soil moisture was extracted from deeper layers (30-45 cm and 45-60 cm) in transplanted rice as compared to aerobic rice during second year. IW:CPE ratio of 1.0 resulted in slightly more soil moisture extraction from 30-45 cm and 45-60 cm soil layers during both the years. Increase in phosphorus level increased the soil moisture extraction from 30-45 cm soil depth compared to control.

From the present study, it can be concluded that in the irrigated command areas the aerobic rice establishment method would be a viable option in terms of water saving and also aerobic rice-maize system will be more productive and profitable and results in higher system water productivity indicating sustainability of aerobic rice-maize system compared to the transplanted rice-maize system.

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Table 1: Interaction effect of rice crop establishment method and irrigation level on maize grain yield (kg ha^{-1})

IW:CPE ratio(I)	Rice crop establishment method (M)					
	2007-08			2008-09		
	Transplanted	**Aerobic**	**Mean**	**Transplanted**	**Aerobic**	**Mean**
0.8	5798	6462	6130	6258	6536	6396
1.0	6381	6728	6554	6808	7072	6940
Mean	6139	6545		6533	6803	
	SEm ±	CD(P=0.05)		SEm ±	CD(P=0.05)	
I	107	217		89	180	
M	68	156		62	199	
I at same or different M	152	307		126	255	
M at same or different I	114	245		109	262	

Table 2: Interaction effect of Irrigation and Phosphorus level on maize grain yield (kg ha^{-1})

P level(kg P_2O_5 ha^{-1})	Irrigation levels (IW: CPE ratio)					
	2007-08			2008-09		
	0.8	**1.0**	**Mean**	**0.8**	**1.0**	**Mean**
0	4751	5125	4938	4938	5734	5340
30	5756	6333	6045	6506	6865	6686
60	6934	7350	7142	7058	7478	7268
90	7079	7408	7244	7084	7674	7379
Mean	6130	6554		6396	6940	
	SEm ±	CD(P=0.05)		SEm ±	CD(P=0.05)	
P	132	292		116	225	
I	107	217		89	180	
Pat same or different I	155	311		179	359	
I at same or different P	149	218		179	359	

Table 3: Influence of crop establishment method of rice on field water use (m^3 ha^{-1}) and field water productivity (kg $m-^3$)

	2007		2008	
	Transplanted	**Aerobic**	**Transplanted**	**Aerobic**
Number of irrigations	33	24	27	16
Irrigation water applied	12200	8400	10100	6500
Effective rainfall during crop period	2238	2238	5795	5795
Quantity of field water used	14438	10638	15895	12295
Field Water Productivity	0.40	0.44	0.34	0.35

Table 4: Influence of rice crop establishment methods and irrigation levels on field water use (m^3 ha^{-1}) and field water productivity (kg m^{-3} grain) in zero-tillage maize and rice-maize system

	2007-08				2008-09			
	Maize after Transplanted rice		Maize after aerobic rice		Maize after Transplanted rice		Maize after aerobic rice	
	IW: CPE ratio							
	0.8	**1.0**	**0.8**	**1.0**	**0.8**	**1.0**	**0.8**	**1.0**
Maize								
Number of irrigations	8	10	8	10	10	13	10	12
Quantity of irrigation water applied	4500	5500	4500	5500	5500	7000	5500	6500
Effective rainfall	339	339	534	534	365	365	--	--
Total quantity of water used	4839	5839	5034	6034	5865	7865	5500	6500
Field Water Productivity	1.33	1.18	1.31	1.16	1.07	0.80	1.17	1.04
Rice-maize system								
Total quantity of water used	21071		16172		22839		18295	
Water productivity	0.56		0.68		0.52		0.60	

Table 5: Consumptive use and crop water productivity of maize as influenced of rice crop establishment method, irrigation and phosphorus level

Treatments	Consumptive use (mm)		Crop water productivity ($kg\ m^{-3}$)		
	2007-08	2008-09	2007-08	2008-09	Mean
Crop establishment methods (M)					
Transplanting rice	343.75	362.46	1.83	1.82	1.83
Aerobic rice	382.79	396.20	1.78	1.76	1.77
Irrigation level (IW:CPE ratio)					
0.8	376.95	404.62	1.68	1.62	1.65
1.0	421.10	458.14	1.69	1.53	1.61
Phosphorus levels (kg P_2O_5 ha^{-1})					
0	292.58	327.56	1.67	1.56	1.62
30	320.85	375.90	2.04	1.82	1.93
60	349.72	396.10	2.03	1.87	1.95
90	361.39	405.20	2.01	1.84	1.93

Data not analyzed statistically

Table 6: Soil moisture extraction pattern (mm) in zero-tillage maize as influenced by crop establishment method irrigation and phosphorus level

Treatments	Soil depth (cm)									
	2007-08					2008-09				
	0-15	15-30	30-45	45-60	Total	0-15	15-30	30-45	45-60	Total
Crop establishment method										
Transplanted rice	137.5	103.12	67.24	35.89	343.75	138.98	100.72	80.16	42.60	362.46
Aerobic rice	158.05	118.79	71.52	34.43	382.79	161.86	116.12	76.24	42.08	396.20
Irrigation level (IW:CPE ratio)										
0.8	142.54	108.26	82.76	43.39	376.95	162.85	122.39	78.92	40.46	404.62
1.0	160.44	124.33	84.24	32.09	401.10	174.06	140.04	94.03	50.01	458.14
Phosphorus level (kg P_2O_5 ha^{-1})										
0	121.03	89.7	53.52	28.26	292.58	129.02	95.27	64.12	39.15	327.56
30	131.34	98.26	61.17	30.08	320.85	150.36	106.77	71.18	47.59	375.90
60	137.89	102.92	75.94	32.97	349.72	159.44	120.83	71.22	44.61	396.10
90	141.09	100.16	82.24	37.90	361.39	162.12	122.83	76.24	44.02	405.20

Influence of Long Term Fertilizer Application on Soil Phosphatase Enzyme Activity and Nutrient Availability in Rice – Rice Cropping System

M. Srilatha*, Palli Chandrasekhar Rao, S.H.K. Sharma and K. Bhanu Rekha

Regional Agricultural Research Station, Acharya N.G.Ranga Agricultural University, Jagtial.

Abstract

Build up of phosphorous in soil was observed under long term fertilizer experiments which were initiated in *kharif* 2000-01 on clay soil at Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Jagtial under All India Coordinated Research Project (AICRP) in a randomised block design for growing rice – rice cropping system involving various doses of N, NP, NPK, NPK with FYM, Zn and S. The data generated during *rabi* 2010-11 (11th crop cycle) was used to report the results. In the present study, the activities of acid phosphatase and alkaline phosphatase in soil were determined during crop growth of rice. Soil samples collected after harvest of rice were analysed for organic carbon, available N, P and K. The activity of acid and alkaline phosphatase in soil at different growth stages of rice revealed that there was an increase in enzyme activity up to active growth stages of crop and later showed decrease. The activities of acid and alkaline phosphatase were significantly higher with application of 150% NPK followed by the treatment 100% NPK +FYM @ 10 t ha^{-1}. Phosphatase activity was at its peak at 60 days after transplanting stage.

Key words: Long term, phosphatase activity, rice, fertilizers, FYM.

Usage of imbalanced fertilizers badly influences production potential and soil health. Integrated nutrient management will not only sustain the crop production but also be effective in improving soil health and enhancing nutrient use efficiency. Enzyme activities are considered as an index of microbiological activity. A better understanding of the role of these soil enzymes in the ecosystem could provide a unique opportunity for an integrated biological assessment of soils due to their crucial role in several soil biological activities, their ease of measurement, and their rapid response to the changes in soil management.

*Corresponding author: sriluss02@gmail.com

Enzyme levels in soil systems vary in amounts primarily due to the fact that each soil type has different amounts of organic matter, composition and activity of living organisms and intensity of the biological processes. Since rice grows in the interactive ecosystem involving soil – microorganism – rice and atmosphere, rice development consequentially affect soil microorganisms and soil enzymatic activities.

Among the various enzymes, phosphatase speeds up soil organic phosphorus decomposition and improves soil phosphorous concentration, which is an important index to assess soil phosphorus bio – availability. Phosphatases are capable of catalysing hydrolysis of esters and hydrides of phosphoric acid. In soil ecosystem, these enzymes are believed to play critical roles in 'P' cycle as evidence shows that they are correlated to 'P' stress and plant growth. Apart from being good indicators of soil fertility, phosphatase enzymes play key role in the soil system (Dick and Tadatabai, 1992). Acid phosphatase provides a potential index of mineralisation of soil organic P. Keeping this in view, a study on the effect of continuous application of fertilizers on soil phosphatase enzyme activity at different growth stages of rice was taken up.

Materials and Methods

The present investigation was carried out in the on-going AICRP on Long Term Fertilizer Experiments initiated in *kharif* 2000-01 at the experimental farm of Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Jagtial. The experimental site is situated at Longitude 78^{o} 45' E to 79^{o} 0 E, Latitude 18^{o}45' N to 19^{o}0 N. The experimental soil at the initiation of the experiment was clayey (Inceptisol) in texture with a soil pH 8.2 (1:2 soil: water ratio), Electrical Conductivity 0.47 dSm^{-1} (1:2 soil: water ratio), organic carbon 0.79 % and 107.6, 19.6 and 364 kg ha^{-1} of available N, P and K. The mean annual total rainfall of the area is 900–1500 mm.

Based on the soil test values for available NPK, 120-60-40 kg N-P_2O_5-K_2O ha^{-1} was fixed as cent per cent optimum recommended dose. The experiment was laid out on permanent basis, the fertilizer and manure doses were then fixed as per treatments. Twelve (11+1) treatments with four replications in a randomised block design (unit plot size 12mx9m) are as follows:

T_1 – 50%NPK ,

T_2 – 100%NPK,

T_3 – 150%NPK,

T_4 – 100% NPK +HW,

T_5 – 100% NPK+$ZnSO_4$ @ 10 kg ha^{-1}(in *kharif*),

T_6 – 100% NP, T_7 – 100% N alone,

T_8 – 100% NPK+FYM@ 10 t ha^{-1}(in each *kharif*),

T_9 – 100% NPK-S,

T_{10} – FYM @ 10 t ha^{-1}(in each *kharif* and *rabi*),

T_{11} – Control (No fertilizers, No manures), T_{12} – Fallow (No crop , No fertilizers).

The nutrients were applied through urea, single super phosphate, muriate of potash and zinc sulphate, where as DAP was used as a source of 'P' in T_9. Recommended chemical control and hand weeding measures were adopted in all the treatments except T_4 where fertilizers and only hand weeding was practiced. The crop was harvested at maturity manually. Soil samples were collected at 30, 60, 90 days after transplanting and at harvest. Acid and alkaline phosphatase activities were assayed by quantifying the amount of p-nitrophenol released and expressed as µg of p-nitrophenol released g^{-1} soil h^{-1}as described by Tabatabai and Bremner (1969).

Soil samples collected after harvest of rice were air dried, ground to pass through 2 mm sieve and then subjected to chemical analysis. For soil organic carbon, soil samples were sieved to pass through a 0.5 mm sieve. Soil organic carbon was determined by the Walkley and Black method (1934), available N by Subbaiah and Asija (1956), P by Olsen method (Olsen *et al.* 1954) and K by ammonium acetate method (Black 1965).

Results and Discussion

The results obtained on the effect of long term fertilizer application on acid phosphatase activity are presented in Table.1 Phosphatase activity (expressed as µg of p-nitrophenol released g^{-1} soil- h^{-1}) in soils collected from different treatments varied significantly during all growth stages of crop. Enzyme activity in soil increased with age of the crop up to 60 days after transplanting. These results are in conformity with those of Vandana *et al.* (2012). Acid phosphatase increase ranged from 64.3 to 90.3, 77.3 to 127.9, 67.6 to 121.3 and 48.8 to 78.1during *kharif* and 72.7 to 120.6, 169.8 to 206.1, 86.1 to 138.7 and 65.6 to 100.5 µg of p-nitrophenol released g^{-1} soil- h^{-1} at 30, 60, 90 DAT and harvest respectively during *rabi* .

Soil enzyme activities increased with increasing rate of NPK application. The highest acid phosphatase activity recorded in 150% NPK treated plot (90.3 and 120.6 µg of p-nitrophenol released g^{-1} soil- h^{-1} in *kharif* and *rabi* respectively) was on par with the application of 100% NPK along with FYM @10 t ha^{-1} (85.1 and 110.5 µg of p-nitrophenol released g^{-1} soil- h^{-1} in *kharif* and *rabi* respectively), compared to other treatments. The acid phosphatase activity was lowest in 100% N alone (64.3 and 72.7 µg of p-nitrophenol released g^{-1} soil h^{-1} in *kharif* and *rabi* respectively), indicating that balanced nutrition of crop is responsible for better proliferation of root and for maximum activity of enzymes.

The increase in activity with integrated application of organic manures along with chemical fertilizer may be attributed to the increasing population of microorganisms like bacteria, etc., due to increased availability of substrate through organic manure there by resulting in high microbial activity and release of these enzymes in to the soil. Mishra *et al*, (2008) reported that application of 100% NPK along with FYM @ 10 t ha^{-1} to maize resulted in increase in phosphatase activity.

Alkaline phosphatase activity ranged from 73.5 to 94.8, 81.8 to 135.2, 70.2 to 125.9, 52.8 to 92.6 in *kharif* and 81.7 to 126.1, 127.9 to 177.4, 85.6 to 151.4 and 69.1 to 109.4 µg of p-nitrophenol released g^{-1} soil h^{-1} at 30, 60, 90 DAT and harvest respectively in *rabi*. The activity of alkaline phosphatase was considerably higher (Fig.1 and 2) than that of acid phosphatase irrespective of treatments. Alkaline phosphatase activity increased sharply up to 60 DAT and there after declined gradually to 30 DAT level in all the treatments. The highest alkaline phosphatase activity was fo und in150% NPK treatment followed by the application of 100% NPK +FYM. In general these enzymes activities were found to be high in *rabi* than *kharif* season.

Effect on available nutrients

Long term application of variable amounts of nutrient levels either alone or in combination, and along with organic manures had profound influence on soil fertility (Table.3). After 11^{th} crop cycle soil organic carbon status increased in all the treatments, highest values were recorded with application of organic manure alone (FYM@10 t ha^{-1}) and along with chemical fertilizers (100% NPK+FYM). 150% NPK Jrecorded highest soil available N (213 kg ha^{-1}), P (42.1 kg ha^{-1} and K (349 kg ha^{-1}) 100% NPK +FYM treatment with 210, 43.2 and 326 kg ha^{-1} respectively indicating that integrated nutrient application improves the soil fertility status equivalent to 150% NPK.

Data on available phosphorous indicates that (Table. 5) available 'P' in treatment 100% NP was 25.8 kg ha^{-1} whereas in treatment receiving 100% N, it was 18.6 kg ha^{-1}. Use of 100% NP over 100% N significantly improved the available P status of the soil. A significant reduction in 'P' was observed under N alone (3.6% depletion from the initial) due to removal of 'P' by the crop in the absence of external source of 'P' (Verma *et al*., 2012).

Conclusions

From the study, it can be concluded that acid phosphatase and alkaline phosphatase activities in soil were significantly increased with application of increased rate of nutrients from 50% recommended dose to 150% of recommended dose of fertilizers. Activity of alkaline phosphatase was higher than acid phosphatase. Enzyme activity increased sharply up to 60 DAT and thereafter decreased gradually to 30 DAT level. Continuous application of fertilizers resulted in build up of available 'P' in soil under long term fertilizer experiments.

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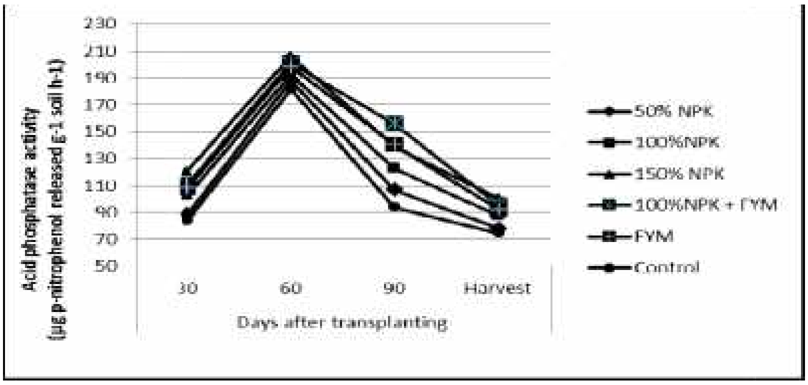

Fig.1 Changes in soil acid phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice (*rabi*).

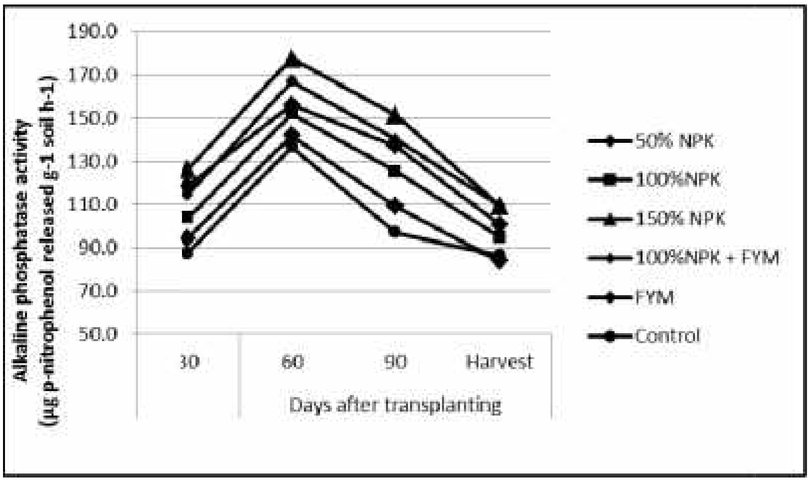

Fig.2 Changes in soil alkaline phosphatase activity (µg p-nitrophenol released g^{-1}soil h^{-1}) at various growth stages of rice (*rabi*).

Table 1: Changes in soil acid phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice during *kharif*

Treatments	*Days after transplanting (kharif)*			
	30	**60**	**90**	**Harvest**
50% NPK	74.6	92.2	88.2	52.1
100%NPK	80.8	110.4	101.3	67.0
150% NPK	90.3	127.9	121.3	78.1
100%NPK + HW	82.5	110.5	100.7	65.5
100%NPK + Zn	83.2	107.6	99.9	64.2
100%NP	65.6	80.7	74.1	55.5
100%N	64.3	77.3	67.6	48.8
100%NPK + FYM	85.1	116.7	112.5	75.5
100%NPK - S	81.9	100.8	103.6	62.3
FYM	87.4	104.2	100.6	74.5
Control	73.1	89.1	80.8	61.1

Fallow	82.9	100.9	98.0	76.8
S.Em+	4.0	7.2	5.5	4.6
CD (0.05)	8.2	14.7	11.2	9.5
CV (%)	7.2	10.1	8.1	10.2

Table 2: Changes in soil acid phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice during *rabi*

Treatments	***Days after transplanting (rabi)***			
	30	**60**	**90**	**Harvest**
50% NPK	88.1	187.9	106.7	77.8
100%NPK	102.2	192.0	122.9	87.4
150% NPK	120.6	206.1	138.7	100.5
100%NPK + HW	102.1	191.5	126.7	91.2
100%NPK + Zn	105.3	194.2	126.9	89.6
100%NP	78.5	177.0	91.5	70.1
100%N	72.7	169.8	86.1	65.6
100%NPK + FYM	110.5	201.1	155.6	95.4
100%NPK - S	101.3	194.0	129.4	89.6
FYM	107.9	198.2	140.2	92.0
Control	83.8	181.9	93.5	74.5
Fallow	100.1	191.5	138.1	95.7
S.Em+	4.4	6.6	6	4.6
CD (0.05)	8.9	13.5	12.2	9.3
CV (%)	6.3	4.9	7.1	7.6

Table 3: Changes in soil alkaline phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice during *kharif*

Treatments	***Days after transplanting(kharif)***			
	30	**60**	**90**	**Harvest**
50% NPK	82.2	86.1	94.0	78.6
100%NPK	87.9	97.6	100.0	82.3
150% NPK	94.8	135.2	125.9	92.6
100%NPK + HW	83.1	97.1	99.0	78.9
100%NPK + Zn	82.6	94.1	99.1	86.1
100%NP	79.9	85.9	79.8	59.2
100%N	73.5	81.8	70.2	52.8
100%NPK + FYM	91.9	123.4	105.1	88.7
100%NPK - S	85.2	99.5	102.0	82.4
FYM	82.2	102.7	104.8	88.5
Control	83.7	85.5	87.5	62.2
Fallow	89.3	110.3	105.3	85.4
S.Em+	3.9	4.4	4.9	3.5
CD (0.05)	7.9	8.9	10.1	7.1
CV (%)	6.5	6.2	7.2	6.3

Table 4: Changes in soil alkaline phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice during *rabi*

Treatments	*Days after transplanting(rabi)*			
	30	**60**	**90**	**Harvest**
50% NPK	94.2	142.0	109.1	83.9
100%NPK	103.8	152.0	125.2	94.9
150% NPK	126.1	177.4	151.4	109.4
100%NPK + HW	102.0	153.6	121.9	96.8
100%NPK + Zn	103.7	149.8	123.1	93.9
100%NP	85.6	132.0	96.7	76.9
100%N	81.7	127.9	85.6	69.1
100%NPK + FYM	114.7	167.0	140.1	109.3
100%NPK - S	100.9	151.6	123.7	94.6
FYM	118.5	156.1	137.0	100.6
Control	87.6	136.6	97.0	86.4
Fallow	114.8	157.8	131.6	103.2
S.Em+	3.3	3.9	3.3	2.4
CD (0.05)	6.7	7.9	6.8	4.9
CV (%)	4.5	3.6	3.9	3.6

Table 5: Soil fertility status after harvest of rice (After 11th crop cycle)

Treatments	**Organic carbon (%)**	**Available Nitrogen (kg ha^{-1})**	**Available Phosphorous (kg ha^{-1})**	**Available Potassium (kg ha^{-1})**
50% NPK	0.81	204	29.5	320
100%NPK	0.8	185	31.1	322
150% NPK	0.81	213	42.1	349
100%NPK + FYM	1.01	210	43.2	326
FYM	1.04	247	38.2	316
Control	0.8	191	20.3	309
CD (0.05)	0.16	NS	6.7	NS

Relative Composition of Egg Parasitoids of Rice Yellow Stem Borer, *Scirpophaga incertulas* (Walker)

N. Rama Gopala Varma*, R. Jagadeeshwar and Chitra Shanker

Rice Section, Acharya N.G. Ranga Agricultural University, Agricultural Research Institute, Rajendranagar and Directorate of Rice Research, Rajendranagar, Hyderabad

Abstract

Studies on the extent of parasitization of yellow stem borer (YSB), *Scirpophaga incertulas (*Wlk.) egg masses for four consecutive years (2009-2012) was assessed in insecticide free paddy field at Rajendranagar, Hyderabad, Andhra Pradesh. The hymenopteran parasitoids, *Telenomus dignus* (Gahan), (Scelionidae), *Tetrastichus schoenobii* Ferriere (Eulophidae) and *Trichogramma japonicum* Ashmead (Trichogrammatidae) were the three important YSB egg parasitoids recorded from this area which played a pivotal role in population regulation of YSB. The peak parasitization ranging from 75.29 to 97.56% was observed during *kharif*, particularly in October. The parasitization during *rabi* varied from 42.60% to 69.79%. In *kharif*, parasitization by *Trichogramma* was more prevalent during September, while that of *Telenomus* and *Tetrastichus* was more during October.

*Corresponding author: varmanrg@gmail.com

Keywords: Scirpophaga incertulas, egg parasitoids, egg parasitization, Trichogramma, Telenomus, Tetrastichus

Rice is one of the most important food crops, with its production crossing 100 million tonnes in 2011-12, accounting for 22.81 per cent of global production. In Andhra Pradesh, rice is cultivated in about 38 lakh hectares with a production of 72.12 lakh metric tonnes and productivity of 2900 kg/ha. Among the various insect pests of rice inflicting yield loss, yellow stem borer, *Scirpophaga incertulas* (Walker) is considered one of the major insect pest of rice, having a potential to cause yield losses ranging from 3%-95% in India (Ghose *et al.*, 1960) while Prasad *et al*. (2007) reported yield losses ranging from 38%-50%. In terms of grain production loss over ecosystems, 1% dead heart, or white ear head, or both phases of stem borer damage would be 108 kg/ha, 174 kg/ha and 278 kg/ha, respectively (Muralidharan and Pasalu, 2006).

Host plant resistance to yellow stem borer is ambiguous. The most commonly used method of control is insecticides, but less effective due to the concealed habit of the larvae. Biological control offers an eco-friendly option for management of this pest. Several workers have reported on egg parasitsation of YSB from different parts of the country. Chandramohan and Chellaiah (1984) identified several parasites of *S. incertulas* from Coimbatore. Hikim (1988) reported that parasitoid activity showed periodical fluctuation coinciding with emergence of YSB moths. Chakraborty (2012) recorded egg parasitoids of YSB from West Bengal. The present study was contemplated to document the extent of parasitism by egg parasitoids against rice yellow stem borer at Rajendranagar, Hyderabad.

Materials and Methods

Field study was conducted at the Rice Section of Agricultural Research Institute, Rajendranagar, Hyderabad, during four consecutive crop years (2009-2012) with variety Sumati during *kharif* and var. Tellahamsa during *rabi.* The observation plot (1000 m^2) was kept pesticide free and the planting time was adjusted to facilitate incidence of rice yellow stem borer and its natural enemies. The entire plot was divided into 4 blocks of equal size, demarcated with bunds and channels. The stem borer egg masses were collected from these unsprayed blocks twice or thrice in a crop season depending upon the availability of egg masses. A minimum of 8-10 egg masses were collected from each block accounting for 30-40 egg masses per observation date.

The collected egg masses were placed individually in separate plastic vials (15 cm long and 2.5 cm wide) and observed periodically for emergence of adult parasitoids. After the emergence, the adult parasitoids were observed under a stereo-zoom microscope (Magnus MSZ with a zoom ratio of 1:7), to identify the respective species and number.

The per cent egg parasitism was computed based on number of live larvae and parasitoid emergence. The species identification of egg parasitoids was done at Directorate of Rice Research, Rajendranagar, Hyderabad.

Results and Discussion

The egg parasitoids of the yellow stem borer, *S. incertulas* prevalent in Rajendranagar were identified as the hymenopterans *Trichogramma japonicum* (Ashm.) (Trichogrammatidae), *Telenomus dignus* (Gahan) (Scelionidae) and *Tetrastichus schoenobii* (Ferr.) (Eulophidae). Perusal of *kharif* 2009 data (Table 1) revealed that 24 per cent of the eggs were parasitized during 2nd week of

October, while maximum parasitization was observed during October 1st (75.29) and 3rd weeks (82.23%). Lakshmi *et al*. (2010) reported 95 per cent egg mass parasitization. The composition of *Tetrastichus, Telenomus* and *Trichogramma* was 43.13 per cent, 25.90 per cent and 6.26 per cent, respectively during 1st week of October, 6.74, 6.99 and 10.30 per cent during October 2nd week and 35.88, 39.77 and 6.38%, during October 3rd week. Chakraborty (2012) reported parasitization by *Trichogramma sp.*, *Telenomus spp.*, and *Tetrastichus spp.* to be 6.12 per cent, 9.53 per cent and 48.44 per cent, respectively.

During *kharif* 2010, total parasitization increased gradually from September 1st week to October 4th week ranging from 39.34% to 97.56%, except during fourth week of September where in only 33.33% eggs were parasitized (Table 1). *Trichogramma* was the predominant egg parasitoid during September, while it was overtaken by *Tetrastichus schoenobii* and *Telenomus dignus* during October 4th week.

Lakshmi *et al*. (2010) reported that *T. schoenobii* was prevalent from September to November and *Trichogramma* and *Telenomus* from September to October, but the activity of egg parasitoids decreased during November. Similar observations were made in the present study. During *kharif* 2011, the egg mass parasitization of *Tetrastichus*, *Telenomus* and *Trichogramma* was 20.8 per cent, 28.0 per cent and 13.2 per cent during October 1st week and 42.5, 6.2 and 22.0 during 2nd week, respectively. The parasitization was relatively low during *kharif* 2012 with 37.96 per cent, 68.97 per cent and 29.45 per cent parasitization, respectively during 3rd week of September, 3rd week of October and 1st week of November. Similarly during *kharif* 2012 *Trichogramma* was the predominant egg parasitoid during September, while *Telenomus* and *Tetrastichus* have become dominant during October.

The total parasitization during *rabi* 2009-10 varied from 51.78% during 4th week of March to 42.60% in 3rd week of April (Table 2). During *rabi* 2009-10 *Telenomus* was the predominant egg parasitoid followed by *Trichogramma* and meager incidence of *Tetrastichus* was noticed.

During *rabi* 2010-11 maximum parasitization (69.79%) was recorded during April 3rd week with *Trichogramma* being the predominant egg parasitoid. Contrastingly, *Tetrastichus* parasitization was more during April 3rd and 4th weeks, while *Telenomus* parasitization was negligible during *rabi* 2010-11. Gupta *et* *al*. (1985) reported egg parasitization of 30.6% and 23.7% respectively during *kharif* and *rabi* by *T. schoenobii* while in the present study the parasitization by *T. schoenobii* ranged from 2.19% to 48.61% during *kharif* and 4.35% to 19.14% during *rabi*.

Even though all the three egg parasitoids were observed, *Trichogramma* was more predominant during September, while the other two egg parasitoids *viz*., *Telenomus* and *Tetrastichus* dominated during October. At Navsari, Gujarat, *T. dignus* and *T. schoenobii* were most abundant parasitoids of YSB eggs (Pandya *et al.,* 1995) and *T. schoenobii* was reported to be second important parasitoid during winter (Hikim, 1988). Senapati *et al.* (1999) reported that the extent of parasitism in different parts of India ranges from 4.0% to 97.2%.

Further, it was observed that there was larval survival in egg masses parasitized by *Trichogramma* but very rarely live larvae were recorded from egg masses parasitized by *Telenomus* and *Tetrastichus*. The extent of parasitization was more during *kharif* than during *rabi*. It was observed that mostly the egg masses were parasitized either by single or two parasitoid species. Occasionally all the three parasitoid species were observed in a single egg mass. Chakraborty (2012) also reported parasitization of YSB egg mass by more than one species *viz*., *Trichogramma spp* + *Telenomus spp* (3.46%), *Telenomus* + *Tetrastichus* (21.06%) and *Trichogramma* + *Tetrastichus* (2.35%).

The study on composition of egg parasitoids of rice yellow stem borer, *S. incertulas* revealed that *Trichogramma japonicum, Telenomus dignus* and *Tetrastichus schoenobii* are predominant egg parasitoids of this region. Considerable variations in egg parasitoid composition were observed across the seasons and in different months within the season. Looking at the predominance of egg parasitoids in *kharif* than in *rabi* there is a greater scope of conserving these parasitoids and augmenting with *Trichogramma* releases, particularly during September and October months, so that the surviving larval population after natural parasitization can be taken care of at the egg stage, through inundation, whereby pesticide usage can be minimized. During *rabi* natural parasitization is relatively low necessitating more inundative releases for effective management of yellow stem borer.

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Table 1: Relative composition of egg parasitoids of rice yellow stem borer in *kharif season* at Rajendranagar

Year	*Trichogramma japonicum*	*Telenomus dignus*	*Tetrastichus schoenobii*	Total **
2009	**% Egg Parasitization***			
October (1st week)	6.26	25.90	43.13	75.29
October (2nd week)	10.30	6.99	6.74	24.00
October (3rd week)	6.38	39.97	35.88	82.23
2010				
September (1st week)	39.34	0.00	0.00	39.34
September (2nd week)	28.70	14.29	0.00	42.99
September (3rd week)	39.40	10.34	6.90	56.64
September (4th week)	16.68	14.46	2.19	33.33
October (4th week)	7.54	41.41	48.61	97.56
2011				
October (1st week)	13.20	28.00	20.8	54.00
October (2nd week)	22.00	6.20	42.5	70.70
2012				
September (3rd week)	24.52	13.44	0.00	37.96
October (3rd week)	11.86	35.91	21.20	68.97
November (1st week)	15.34	11.17	2.94	29.45

* Each value is a mean of 30 to 40 egg masses

** The total indicates the extent of parasitization observed in the specified week

Table 2: Relative composition of egg parasitoids of rice yellow stem borer in *rabi season* at Rajendranagar

Year	*Trichogramma japonicum*	*Telenomus dignus*	*Tetrastichus schoenobii*	Total**
2009-10	**% Egg Parasitization***			
March (4th week)	19.74	26.33	5.71	51.78
April (3rd week)	8.57	34.03	0.00	42.60
2010-11				
April (1st week)	34.10	8.70	4.35	47.15
April (2nd week)	52.40	0.31	17.38	69.79
April (4th week)	32.20	0.57	19.14	51.96

* Each value is a mean of 30 to 40 egg masses

** The total indicates the extent of parasitization observed in the specified week

Study on Bio-Efficacy of Certain Acaricides Alone and in Combination with Propiconazole against Rice Panicle Mite, *Stenotarsonemus Spinki* Smiley

A. Venkat Reddy*, R. Sunitha Devi, S. Dhurua and D. Vishnu Vardhan Reddy

Regional Agricultural Research Station, Mulugu Road, Warangal-506007, Andhra Pradesh

Abstract

Four acaricides (Diafenthiuron, Propargite, Dicofol and Profenophos) and in combination with fungicide (Propiconazole) were evaluated for their efficacy against rice panicle mite for the management of grain damage during field trials conducted at Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Warangal, A.P for three consecutive *kharif* seasons of 2010, 2011 and 2012. Among all the treatments, Dicofol 18.5 EC + Propiconazole 25 EC @ 5 ml+1 ml/l was found to be the most effective treatment followed by Diafenthiuron 50 WP + Propiconazole @ 1.5 g + 1 ml/l and Profenophos 50 EC + Propiconazole 25 EC @ 2 ml+1ml/l. Among all the treatments, acaricides in combination with fungicide gave higher efficacy when compared to acaricides alone.

Key words: Rice, panicle mite, acaricide, fungicide, bio-efficacy.

* Corresponding author: adrrars_wgl@yahoo.co.in

Rice, the staple food of nearly half of the humanity is mainly grown and consumed in Asian countries. India is number one in area and it ranks second in rice production, but per hectare yield or productivity is low.

Traditionally insect pests, diseases and weeds are the triple evils responsible for lower yields of rice in India. Of late, mites are assuming major status in rice crop in India as well as in Andhra Pradesh. Among different species of mites associated with rice crop, the rice panicle mite or sheath mite is most important. The rice panicle mite or sheath mite, (*Stenotarsonemus spinki)* alone and in association with sheath rot fungus, (*Acrocylindrium oryzae)* causes grain discoloration, ill-filled, chaffy grains and often cause heavy losses. It has been reported that this mite caused yield losses ranging from 4.9% to 23.7% (Natalie *et al*., 2009). Several studies were conducted to test the efficacy of insecticides alone against panicle mite (Bhanu *et al.*, 2006; Laxmi *et al.*, 2008). However, adequate information is not available on the efficacy of acaricides alone and in combination with fungicides. Therefore, the present study was conducted to evaluate the efficacy of different acaricides alone and in combination with fungicide, propiconazole against rice panicle mite under field conditions.

Materials and Methods

Field trials were conducted at Regional Agricultural Research Station, Warangal, Andhra Pradesh for three years i.e., 2010, 2011 and 2012 *Kharif* seasons to evaluate the efficacy of certain acaricides alone and in combination with fungicide-Propiconazole against panicle mite. The trials were laid in a Randomized Block Design (RBD) with nine treatments and three replications with a plot size of 20 m^2. The popular rice variety, BPT-5204 which is susceptible to panicle mite was chosen. All the recommended package of practices were implemented in all the treatments except treatment sprayings. Three sprayings of chemicals were given at panicle initiation stage, boot leaf stage and at 50 per cent panicle emergence using knapsack sprayer with a spray fluid volume of 500 l/ha. Observations were recorded on number of healthy grains, number of discolored grains, number of chaffy grains per panicle, grain yield per plot and the data was expressed as per cent discolored grains+ chaffy grains and per cent reduction of discolored grains + chaffy grains over control and grain yield per hectare.

Results and Discussion

The pooled data for three years in respect of per cent discolored grains + chaffy grains, per cent reduction over control and grain yield/ha is depicted in Table 1. The results indicated that among all the treatments, Dicofol 18.5 EC + Propiconazole 25 EC @ 5 ml + 1 ml/l was significantly highly effective , where in the per cent grain discoloration + chaffy grains was the lowest (8.3%) and per cent reduction of grain discoloration + chaffy grains was the highest (60.8%) with highest grain yield of 7049 kg/ha. The next best treatments were: Diafenthiuron 50 WP + Propiconazole 25 EC @ 1.5 g + 1 ml/l (9.8%, 53.8% respectively) and Profenophos 50 EC + Propiconazole 25 EC @ 2 ml + 1 ml/l (10.1%, 52.4% respectively) and were found to be on par with each other in efficacy and grain yield (6768 and 6698 kg/ha respectively). The lowest efficacy was recorded with Propargite 57 EC + Propiconazole 25 EC @ 1.5 ml + 1 ml/t where in, the per cent grain discoloration + chaffy grain was the highest (13.8%) and the per cent reduction over control was lowest (33.8%). Among the treatments, all the acaricide treatments alone have shown significantly lower efficacy by showing highest grain discoloration + chaffiness and lowest per cent reduction over control compared to combination of acaricides with propiconazole. Among all the treatments, significantly lowest efficacy was noticed with Progargite 57 EC @ 1.5 ml/l (15.3% and 27.8% respectively) followed by Diafenthiuron 50 WP @ 1.5 g/l (14.3%, 32.5%, respectively) and Dicofol 18.5 EC @ 5 ml (13.9%, 34.4%, respectively) which were found on par with each other. Among the acaricides alone treatments, Profenophos 50 EC @ 2 ml/lt was found to be the best treatment by showing relatively lower percent grain discoloration + grain chaffiness (12.2%) and relatively higher percent reduction (34.4%) over control.

With respect to grain yield, significantly highest yield was observed with Dicofol 18.5 EC + Propiconazole 25 EC @ 5 ml + 1 ml/l (7049 kg/ha) followed by Diafenthiuron 50 WP + Propiconazole 25 EC @ 1.5 g + 1 ml (6768 kg/ha). The lowest grain yield was recorded in Propargite 57 EC @ 1.5 ml/l (6358 kg/ha) but significantly superior over untreated control (5667 kg/ha).

The present finding on superior efficacy of acaricides in combination with fungicides compared to acaricides alone was in conformity with findings of Suresh *et al.* (2013). Bhanu *et al.* (2006) and Lo*et al.* (1981) also reported superior efficacy of acaricides like Dicofol and Profenophos against panicle mite in rice. In India, grains infested with *S.spinki* were described as being discolored and pathogenic fungi were isolated from mite (Rao and Prakash, 2003). Chen *et al*, (1979) found that *S.spinki* carried spores of *Acrocylindrium Oryzae* on their body and attributed the plant symptoms to a combination of *S.spinki* damage and disease. Miticides that have been tested under laboratory conditions reported to cause more than 95 per cent mortality of adult *S.spinki*. Field trials conducted in India reported up to 90 per cent mortality following treatments with certain acaricides (Bhanu *et al.*, 2006 and Ghosh *et al*., 1998). The present findings clearly indicate that apart from panicle mite, several pathogens especially sheath rot fungus, *Acrocylindrium oryzae* was responsible for grain damage. Hence, invariably an effective fungicide in combination with effective acaricide may be recommended to the farmers for reducing grain damage associated with panicle mite and pathogens. Based on overall performance, Dicofol 18.5 EC +

Propiconazole 25 EC @ 5 ml + 1 ml/l followed by Diafenthiuron 50 WP + Propiconazole 25 EC 1.5 g + 1 ml and Profenophos 50 EC + Propiconazole 25 EC @ 2 ml + 1 ml/l may be suggested to the farmers for managing grain damage due to panicle mite in association with pathogens.

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Table 1. Efficacy of acaricides alone and in combination with fungicide in the management of grain damage due to rice panicle mite

Treatments	Dose/l	% discolored grains + Chaffy grains				% Reduction of discolored grains + chaffy grains over control				Grain yield (kg/ha)			
		2010	2011	2012	Pooled	2010	2011	2012	Pooled	2010	2011	2012	Pooled
Diafenthiuron 50 WP + Propiconazole 25 EC	1.5g+1.0ml	11.3	10.7	7.5	9.8	19.3	64.0	62.1	53.8	7855	7575	4875	6768
Propargite 57 EC + Propiconazole 25 EC	1.5ml+1.0ml	11.3	17.0	13.1	13.8	19.3	42.8	33.8	34.9	7315	7426	4650	6500
Dicofol 18.5 EC+ Propiconazole 25 EC	5.0ml+1.0ml	8.0	9.9	6.9	8.3	42.9	66.7	65.2	60.8	7950	8182	5015	7049
Profenephos 50 EC+ Propiconazole 25 EC	2.0ml+1.0ml	12.3	12.8	5.3	10.1	12.1	56.9	73.2	52.4	7710	7236	5150	6698
Diafenthiuron 50 WP	1.5g	13.7	16.1	13.0	14.3	2.1	45.8	34.3	32.5	7470	7055	4580	6368
Propargite 57 EC	1.5ml	12.7	15.9	15.6	15.3	9.3	46.5	21.2	27.8	7475	7135	4465	6358
Dicofol 18.5 EC	5.0ml	15.0	14.5	12.1	13.9	7.1	51.2	38.8	34.4	7590	6575	4715	6793
Profenephos 50 EC	2.0ml	11.0	15.2	10.5	12.2	21.4	48.8	47.0	42.5	7530	7435	4890	6618
Untreated control	-	14.0	29.7	19.8	21.2	-	-	-	-	6375	6507	4120	5667
CD (0.05%)		3.2	2.5	2.7	2.8	2.5	5.1	4.8	4.5	355.0	215.7	175.5	248.9
SEm±		1.5	1.2	1.3	1.3	1.2	2.4	2.3	2.1	159.0	103.2	82.8	115.0

Compatibility of Fungicides and Insecticides Targeting Sheath Blight and Major Rice Pests

V. Bhuvaneswari* and S. Krishnam Raju

Department of Plant Pathology, Andhra Pradesh Rice Research Institute & Regional Agricultural Research Station, Maruteru,, Acharya N.G. Ranga Agricultural University, Andhra Pradesh

Abstract

Three fungicides and six insecticides at recommended concentrations were evaluated as tank mix in various fungicide and insecticide combinations for their efficacy against sheath blight, brown plant-hopper and leaf folder and to investigate their compatibility as tank mix application for the purpose of reducing the application cost in the event of simultaneous occurrence of both diseases and pests during crop growth period. Among the different combinations tested, pymetrozine @ 0.5 g/l in combination with hexaconazole @ 2 ml/l recorded less sheath blight incidence (9.1%) severity (14.8%) and also lesser number of plant-hoppers (0.5/hill) followed by pymetrozine @ 0.5 g/l + validamycin @ 2 ml/l (9.6%, 15.0% and 0.7/hill) and combination product of imidacloprid + ethiprole @ 0.8 g/l + hexaconazole @ 2 ml/l (9.2%, 18.2% and 0.4/hill) compared to untreated check where the incidence and severity of sheath blight was 93.6% and 81.9% respectively. The number of plant-hoppers in untreated check plot was 26/hill. Similarly, chlorantraniliprole @ 0.3 ml/l in combination with hexaconazole @ 2 ml/l (6.3% WE) gave less incidence (8.3%) and severity of sheath blight (12.8%) and also less stem borer and lesser leaf folder damaged leaves per hill (1.9) followed by pymetrozine @ 0.5 g/l + validamycin @ 2 ml/l (9.6%, 15.0% and 1.2/hill, 12.5% WE). There was no reduction in the efficacy of these insecticides and fungicides when used as tank mix and phytotoxicity symptoms were not observed in any of the treatments. Thus, all the insecticides and fungicides combinations used in the present investigation are compatible with each other and can be safely combined as tank mix for the control of rice pests and diseases, thus, saving labour costs.

Key words: Insecticides, fungicides, compatibility, rice, sheath blight, brown plant-hopper and leaf folder.

*Corresponding author: bhuvanavk2001@gmail.com

Rice (*Oryza sativa* L.) is the primary source of food for more than half of the world's population. Occurrence of diseases and insect pests together in rice demands the necessity of fungicidal and insecticidal application at the same place and time. In many endemic areas, sheath blight, brown planthopper (BPH), leaf folder and stem borer occur at the same stage of the crop growth. Therefore, a combined application of effective fungicides and insecticides is a practical necessity. In Andhra Pradesh, Godavari delta farmers are regularly going for 2-3 sprays in rice crop, and mixed combinations of fungicides and insecticides is a common practice in view of labour shortage at these locations. Keeping this in view, the study was undertaken with effective fungicides like hexaconazole, validamycin and trifloxystrobin 25% + tebuconazole 50% WG @ 2.0 ml/l, 2.0 ml/l and 0.4 g/l, respectively along with the effective insecticides like buprofezin, pymetrozine, acephate, chlorantraniliprole, dinotefuran and imidacloprid + ethiprole 80% WG @ 1.6 ml/l, 0.5 g/l, 1.5 g/l, 0.3 ml/l, 1.8 g/l and 0.8 g/l, respectively to find their efficacy on sheath blight and insect pests like BPH, leaf folder and stem borer as well as the compatibility of the test fungicides and insecticides.

Materials and Methods

The experiments were conducted during the *kharif* 2011 and 2012 seasons in Randomized Block Design. Three fungicides *viz*., hexaconazole 5% EC, validamycin 3% l and trifloxystrobin 25% + tebuconazole 50% (Nativo 75% WG) @ 2 ml/l, 2 ml/l and 0.4 g/l, respectively and six insecticides *viz*., buprofezin 25% SC, pymetrozine 50% WG (Plenum), acephate 75% SP, chlorantraniliprole 18.5% SC (Coragen), dinotefuran 20% SG (Token) and imidacloprid + ethiprole 80% WG (Glamor) @ 1.6 ml/l, 0.5 g/l, 1.5 g/l, 0.3 ml/l, 1.8 g/l, and 0.8 g/l, respectively, were evaluated as tank mix of fungicide and insecticide combinations for their efficacy against sheath blight, brown planthopper and leaf folder and to investigate their compatibility as tank mix application for the purpose of reducing the application cost in the event of simultaneous occurrence of both diseases and pests during crop growth period. An untreated control was also maintained for comparison. Popular susceptible rice variety, MTU-7029 (Swarna) was transplanted during *kharif* 2011 and 2012 seasons in a randomized block design with 10 treatments and three replications. A spacing of 15 x 15 cm was adopted in a gross plot size of 9.945 sq m. A pure culture of a virulent isolate of *Rhizoctonia* *solani* was multiplied on typha leaf bits. Inoculation with *R. solani* was carried out at maximum tillering stage (Bhaktavatsalam *et al*., 1978). The colonized typha bits were placed between the tillers of rice plant, 5-10 cm above the water level. The data on the disease incidence and subsequent spread were collected from the date of first incidence of the disease till 30 days after final spray. The per cent disease incidence and severity was calculated from the data collected from 25 hills of each treatment in each replication as per the Standard Evaluation System for rice (IRRI, 1996). The disease incidence and severity data were transformed into arc sine values before statistical analysis. Similarly natural incidence in these treatments was also recorded. The grain yield was recorded from each gross plot and calculated to kg/ha. The data was subjected to statistical scrutiny, and the results are furnished.

The disease and pests were first noticed in the experimental plots at maximum tillering stage during both seasons. Three fungicidal and insecticidal combination sprays were given at 15 days interval starting from the appearance of initial disease symptoms and pest incidence depending upon the initial disease symptoms/insect damage and the subsequent pest pressure. A spray fluid of 500 L/ha was used to ensure thorough coverage of the plants. Symptoms of phytotoxicity, if any, were also recorded at 5 and 10 days after the imposition of the treatments. Yield data was also recorded.

Results and Discussion

During 2011, the data revealed that among different fungicide and insecticide combinations used for the control of sheath blight, planthoppers and leaf folder, combination product of imidacloprid + ethiprole @ 0.8 g/l + hexaconazole @ 2.0 ml/l has recorded less sheath blight incidence (7.3%) severity (14.4%) and also lesser number of plant-hoppers (0.1 per hill) closely followed by trifloxystrobin 25%+ tebuconazole 50% WG @ 0.4 g/l in combination with buprofezin @ 1.6 ml/l (5.4%, 11.8%, 3/hill), pymetrozine @ 0.5 g/l + validamycin @ 2 ml/l (11.6%, 18.5%, 0.3/hill), pymetrozine @ 0.5 g/l + hexaconazole @ 2 ml/l (13.8%, 19.6%, 0.6/hill) and buprofezin @ 1.6 ml/l + hexaconazole @ 2 ml/l (5.6%, 11.9%, 6.9/hill) compared to untreated check where the incidence and severity of sheath blight was 87.1 and 85.7 per cent respectively. The number of planthoppers per hill in untreated check plot was 38.1 per hill. No significant differences were found among treatments with respect to leaf folder damaged leaves. In 2011, the incidence of leaf folder was very low.

While, chlorantraniliprole @ 0.3 ml/l in combination with hexaconazole @ 2 ml/l gave less disease incidence (12.2%) and severity of sheath blight (18.5%) and also lesser per cent white ears (6.3) closely followed by acephate @ 1.5 g/l + hexaconazole @ 2 ml/l (11.6%, 15.3%, 7.5%) compared to control where the per cent white ears was 19.6 (Tables 1 and 2). This confirms that the fungicides and insecticides involved in the trial are compatible in all fungicide insecticide combination from the point of sheath blight, brown planthopper and stem borer management.

During 2012, the data presented in Tables 1 and 2 revealed that among different fungicide and insecticide combinations, dinotefuran @ 1.8 g/l + hexaconazole @ 2 ml/l combination has recorded less sheath blight incidence (3.8%) severity (7.8%) and also lesser number of planthoppers (0.2/hill) closely followed by combination of pymetrozine @ 0.5 g/l + hexaconazole @ 2 ml/l (4.5%, 10.1% and 0.3/hill) and combination of (imidacloprid + ethiprole) @ 0.8 g/l + hexaconazole @ 2 ml/l (11.1%, 22.0% & 0.7/hill) compared to untreated check where the incidence and severity of sheath blight was cent per cent and 78.1 per cent respectively. The number of plant-hoppers per hill in untreated check plot was 13.9 per hill. Similarly chlorantraniliprole @ 0.3 ml/l in combination with hexaconazole @ 2 ml/l gave less disease incidence (4.4%) and severity of sheath blight (7.2%) and also lesser leaf folder affected leaves per hill (3.7), reveal that the combinations did not in any way lower the effectiveness of the fungicides against sheath blight and insecticides against BPH and leaf folder. Phytotoxicity symptoms were not observed in any of the treatments which indicated the positive compatibility of the evaluated chemicals.

The pooled data revealed that among different fungicide and insecticide combinations used for the control of sheath blight, planthoppers and leaf folder, combination of pymetrozine @ 0.5 g/l + hexaconazole @ 2 ml/l has recorded less sheath blight incidence (9.1%) severity (14.8%) and also lesser number of plant hoppers (0.5/hill) closely followed by pymetrozine @ 0.5 g/l + validamycin @ 2 ml/l (9.6%, 15.0%, 0.7/hill) and combination of imidacloprid + ethiprole @ 0.8 g/l + hexaconazole @ 2 ml/l (9.2%, 18.2% and 0.4/hill), compared to untreated check where the incidence and severity of sheath blight was 93.6% and 81.9%, respectively. The number of planthoppers per hill in untreated check plot was 26per hill. The other combinations *viz*., buprofezin @ 1.6 ml/l + trifloxystrobin 25% + tebuconazole 50% WG @ 0.4 g/l (8.3%, 15.7%, 4.2/hill), buprofezin @ 1.6

ml/l + hexaconazole @ 2 ml/l (4.8%, 9.9%, 5.5/hill) and dinotefuran @ 1.8 g/l + hexaconazole @ 2 ml/l (19.4%, 26.8%, 9.5/hill) were also found superior over control. Similarly chlorantraniliprole @ 0.3 ml/l in combination with hexaconazole @ 2 ml/l gave less incidence (8.3%) and severity of sheath blight (12.8%) and also lesser leaf folder infested leaves per hill (1.9) closely followed by pymetrozine @ 0.5 g/l + validamycin @ 2 ml/l (9.6%, 15%, 1.2/hill) compared to control where the number of leaf folder damaged leaves were 4.20 per hill (Tables 1 and 2). The overall results revealed that tank mixing of fungicides with insecticides involved in the present studies did not reduce the efficacy of the fungicides against rice sheath blight and that of insecticides against brown planthopper and leaf folder. Hence, they are compatible with each other for spray application to control the rice pests. These findings are in conformity with the findings of Singh *et al*. (2010), where in it was reported that the combination treatments of fungicides (tricyclazole and iprobenphos) and insecticides (indoxacarb and cartap hydrochloride) were biologically as effective as their individual treatments against neck blast, leaf folder and stem borer of rice, respectively during *kharif* 2006 and 2007 along with corresponding grain yield in Taraori Basmati. Similar reports were reported by Prajapati *et al.* (2005) that insecticide triazophos (20% EC @ 0.02%) alone or tank mixed with fungicides carbendazim (50% WP @ 0.05%) and tricyclazole (75% WP @ 0.04%) was found effective in controlling leaf folder damage as well as white backed plant-hoppers as compared to untreated control. Bhatnagar (2004) reported that the combination of cartap (Padan 50% WP) and tricyclazole (Beam 75% WP) was effective in reducing the damage by rice leaf folder and blast, and found to be compatible.

Thus, the effectiveness of the six insecticides *viz*., buprofezin, pymetrozine, acephate, chlorantraniliprole, dinotefuran and imidacloprid + ethiprole did not in any way get hindered by mixing with the fungicides. All the treatments with fungicide-insecticide combinations had significantly higher grain yield as compared to the control.

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Table 1. Efficacy of fungicides and insecticides as tank mix against sheath blight of rice

S. No	Treatments	Dose/L	*Disease incidence (%)			*Disease severity (%)			*Yield (kg/ha)		
			2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T1	Buprofezin 25% SC (Applaud) + hexaconzole 5% EC	1.6 ml + 2.0 ml	5.6 (13.6)^{a}	4.0 (11.5)^{a}	4.8 (12.6)^{a}	11.9 (20.1)^{a}	8.0 (16.1)^{a}	9.9 (18.3)^{a}	7859^{a}	3776^{a}	5817^{a}
T2	Buprofezin + validamycin 3% L	1.6 ml + 2.0 ml	32.7 (34.9)^{c}	22.3 (27.4)^{b}	27.5 (31.6)^{d}	45.4 (42.3)^{b}	27.4 (30.7)^{c}	36.4 (37.1)^{d}	7196^{ab}	3385^{a}	5291^{b}
T3	Buprofezin + (trifloxystrobin 25% + tebuconazole 50% WG (Nativo 75% WG)	1.6 ml + 0.4 g	5.4 (12.8)^{a}	11.2 (18.7)^{a}	8.3 (16.5)^{a}	11.8 (20.0)^{a}	19.5 (26.0)^{b}	15.7 (23.3)^{b}	7864^{a}	3522^{a}	5693^{a}
T4	Pymetrozine 50% WG (Plenum) + hexaconazole	0.5 g + 2.0 ml	13.8 (21.8)^{b}	4.5 (12.1)^{a}	9.1 (17.5)^{a}	19.6 (26.1)^{a}	10.1 (18.4)^{a}	14.8 (22.6)^{ab}	7615^{a}	3759^{a}	5687^{a}
T5	Pymetrozine + validamycin	0.5 g + 2.0 ml	11.6 (19.7)^{b}	7.5 (14.2)^{a}	9.6 (17.9)^{b}	18.5 (25.5)^{a}	11.4 (18.3)^{a}	15.0 (22.6)^{ab}	7479^{a}	3731^{a}	5605^{a}
T6	Acephate 75% SP + hexaconazole	1.5 g + 2.0 ml	11.6 (19.7)^{b}	6.6 (14.4)^{a}	9.1 (17.6)^{ab}	15.3 (22.9)^{a}	12.0 (20.0)^{ab}	13.7 (21.7)^{a}	7954^{a}	3611^{a}	5783^{a}
T7	Chlorantraniliprole 18.5% SC (Coragen) + hexaconazole	0.3 ml + 2.0 ml	12.2 (19.9)^{b}	4.4 (10.9)^{a}	8.3 (16.4)^{a}	18.5 (24.9)^{a}	7.2 (13.5)^{a}	12.8 (20.8)^{a}	7458^{a}	3814^{a}	5636^{a}
T8	Dinotefuron 20% SG (Token) + hexaconazole	1.8 g + 2.0 ml	34.9 (36.1)^{c}	3.8 (11.2)^{a}	19.4 (26.0)^{c}	45.8 (42.6)^{b}	7.8 (16.2)^{a}	26.8 (31.1)^{c}	6948^{bc}	3817^{a}	5383^{ab}
T9	(Imidacloprid + ethiprole 80% WG) (Glamor) + hexaconazole	0.8 g + 2.0 ml	7.3 (15.2)^{ab}	11.1 (18.8)^{ab}	9.2 (17.5)^{a}	14.4 (21.8)^{a}	22.0 (27.6)^{bc}	18.2 (25.2)^{b}	8242^{a}	3724^{a}	5983^{a}
T10	Control	--	87.1 (69.0)^{d}	100 (90.0)^{c}	93.6 (75.3)^{e}	85.7 (67.8)^{c}	78.1 (62.2)^{d}	81.9 (64.9)^{e}	6010^{c}	2116^{b}	4063^{c}
		CD(P=0.05)	6.8	9.8	5.0	7.7	8.9	4.3	1180.1	988.1	635.4
		CV	15.1	25.0	11.7	14.3	20.7	8.7	9.2	16.3	6.7

*Mean of three replications

Figures in the parentheses are arc sine transformed values.

Table 2. Efficacy of insecticides and fungicides as tank mix against major rice pests

S. No	Treatments	Dose/L	*BPH (No./hill)			*Leaf folder infested leaves/hill			White ears (%)
			2011	2012	Pooled	2011	2012	Pooled	2011
T1	Buprofezin 25% SC (Applaud)+ hexaconzole 5% EC	1.6 ml + 2.0 ml	6.9 (2.5)^{b}	4.2 (2.0)^{bc}	5.5 (2.3)^{bc}	0.0 (0.0)	5.5 (2.3)^{b}	2.7 (1.7)^{b}	14.1 (22.0)^{b}
T2	Buprofezin + validamycin 3% L	1.6 ml + 2.0 ml	3.8 (1.9)^{b}	5.6 (2.3)^{c}	4.7 (2.1)^{b}	0.1 (0.2)	4.9 (2.2)^{b}	2.5 (1.6)^{b}	8.5 (16.6)^{a}
T3	Buprofezin + (trifloxystrobin 25% + tebuconazole 50% WG (Nativo 75% WG)	1.6 ml + 0.4 g	3.0 (1.7)^{b}	5.3 (2.1)^{c}	4.2 (2.0)^{b}	0.0 (0.0)	7.2 (2.7)^{c}	3.6 (1.9)^{bc}	20.7 (26.9)^{c}
T4	Pymetrozine 50% WG (Plenum) + hexaconazole 5% EC	0.5 g + 2.0 ml	0.6 (0.7)^{a}	0.3 (0.5)^{a}	0.5 (0.7)^{a}	0.0 (0.0)	4.5 (2.1)^{b}	2.3 (1.5)^{ab}	12.5 (19.4)^{ab}
T5	Pymetrozine + validamycin 3% L	0.5 g + 2.0 ml	0.3 (0.4)^{a}	1.1 (0.8)^{ab}	0.7 (0.7)^{a}	0.0 (0.0)	2.4 (1.5)^{a}	1.2 (1.1)^{a}	14.6 (22.4)^{bc}
T6	Acephate 75% SP + hexaconazole 5% EC	1.5 g + 2.0 ml	28.1 (5.3)^{d}	4.2 (2.0)^{bc}	16.1 (4.0)^{d}	0.1 (0.1)	4.3 (2.1)^{b}	2.2 (1.5)^{ab}	7.5 (15.7)^{a}
T7	Chlorantraniliprole 18.5% SC (Coragen) + hexaconazole 5% EC	0.3 ml + 2.0 ml	80.4 (9.0)^{f}	20.1 (4.3)^{d}	50.2 (7.1)^{f}	0.0 (0.0)	3.7 (1.9)^{ab}	1.9 (1.4)^{a}	6.3 (13.6)^{a}
T8	Dinotefuran 20% SG (Token) + hexaconazole 5% EC	1.8 g + 2.0 ml	18.7 (4.3)^{c}	0.2 (0.4)^{a}	9.5 (3.1)^{c}	0.0 (0.0)	5.5 (2.3)^{b}	2.7 (1.6)^{b}	10.0 (18.2)^{a}
T9	(Imidacloprid + ethiprole 80% WG) (Glamor) + hexaconazole 5% EC	0.8 g + 2.0 ml	0.1 (0.2)^{a}	0.7 (0.7)^{a}	0.4 (0.6)^{a}	0.0 (0.0)	6.0 (2.4)^{bc}	3.0 (1.7)^{b}	10.6 (18.6)^{a}
T10	Control	--	38.1 (6.2)^{e}	13.9 (3.7)^{d}	26.0 (5.1)^{e}	0.1 (0.2)	8.3 (2.8)^{c}	4.2 (2.0)^{c}	19.6 (26.2)^{c}
		CD(0.05)	0.8	1.2	0.8		0.5	0.4	6.7
		CV	14.2	35.9	15.8	NS	12.7	12.8	23.0

*Mean of three replications.

Figures in the parentheses are arc sine transformed values.

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1. Mukherjee, J.N. 1953. The need for delineating the basic oil and climatic regions of importance to the plant industry. *Journal of Indian Society of Soil Science* 1: 1-6
2. Scott, J.M. 1984. Catabolism of folates. P.307-327. In R.L. Blackley and S.J. Benkovic (ed.) Folates and Pterims Vol.1. John Wiley & Sons, New York
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