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Review Article
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REMOTE SENSING FOR PEST DAMAGE: PRESENT STATUS AND POTENTIAL APPLICATION- CASE STUDIES FROM INDIA

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ABSTRACT

Traditionally, pest and disease assessment of crop plants is being done by visual approach i.e., relying up on human eye and brain to assess their incidence. However, they are time consuming,laboriousoften error prone.Remote sensing technologies offer ample scope towards developing an alternate means that can enhance or supplement the traditional approaches for monitoring and control. Remote sensing of damage due to pests and diseses in crops is based on the assumption that stresses interferes with photosynthesis and physical structure of the plant at tissue and canopy level. Thus,affects the absorption of light energy and alter the reflectance spectrum. Detailed studies into spectral reflectance of crops infested with pests can help to identify unique and specific spectral signatures that can be used for detecting the damage. Remote sensing platforms can be ground based,airborne or space borne. Depending on the spectral resolution and contiguous nature of spectral recording the sensors can be either multispectral or hyperspectral. Remote sensing technology could provide timely information on spatial variability of pest damage over a large area. Thus can guide scouting efforts and crop protection advisory in an effective manner. A lot of research work has been done on this aspect world over. However, in India, the studies are limited to few crops and pests. Thisreview provides an overview of the research work done in India and potential application of this technology in crop protection.With the advancements in the communication, aviation and space technology, remote sensing has immense potential in the future agriculture.

Remote sensing for automated detection, quantification, diagnosis, and identification of plant diseases is particularly crucial for precision agriculture. Innovative imaging sensor tools are capable of improving spatial and spectral resolution accuracies that enable the assessment of spatial disease manifestation and also the evaluation of early detection approaches, aiming to detect changes in leaf optical behaviour due to infection occurrence, which are not yet perceived by the human vision system. Remote sensing may provide a better means to objectively quantify crop stress than visual methods and it can be used repeatedly to collect sample measurements non-destructively and non-invasively (Nilson 1995; Nutter et al. 1990). Traditionally, insect pest and disease assessment of crop plants is being done by visual approach which are often time consuming and labour intensive. Advances in the field of remote sensing offers scope for exploiting these technologies towards developing alternate means that can enhance or supplement the traditional approaches. There are several reviews published from time to time on remote sensing of biotic stress (Jackson 1986; Riley 1989; Hatfield and Pinter 1993; Nilsson 1995; Everitt *et al*., 2003; West *et al*., 2003; Kelly and Guo 2007; Prabhakar *et al*., 2012).

Principle of operation of remote sensing for crop damage assessment

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object under investigation. When electromagnetic energy is incident on any feature on the earth surface, three energy reactions with the feature are possible: reflection, absorption and/or transmission (Lillesand et al., 2004). The portion of energy reflected, absorbed or transmitted will vary for different earth features depending on their material type and condition. Even within a given feature type, the portion of reflected, absorbed and transmitted energy will vary at different wavelengths. Thus, two features may be distinguishable in one spectral range and be very different in another wavelength band. Because many remote sensing systems operate in the wavelength regions in which reflected energy

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predominates, the reflectance properties of earth surface are very important. The reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected (Panda 2005). Reflectance is measured as a function of wavelength and is called spectral reflectance. A graph of the spectral reflectance of an object as a function of wavelength is termed as 'spectral reflectance curve'.

providing potential for remote sensing diagnosis of vegetation stress. Natural growth processes (e.g. increase of biomass, development, maturation, senescence, plant architecture and natural fluctuations in hydraulic properties) and the related biochemical changes, for instance the concentration of chlorophyll and other pigments, also have an impact on the amount of solar energy that is reflected, absorbed, and transmitted by plants (Carter 1993; Lillesand *et al.*, 2004; Ustin *et al.*, 2002). Thus, research into vegetative spectral reflectance can help to gain a better understanding of the physiological, chemical and physical processes in plants and to detect plant stress when remedial action may still be effective.

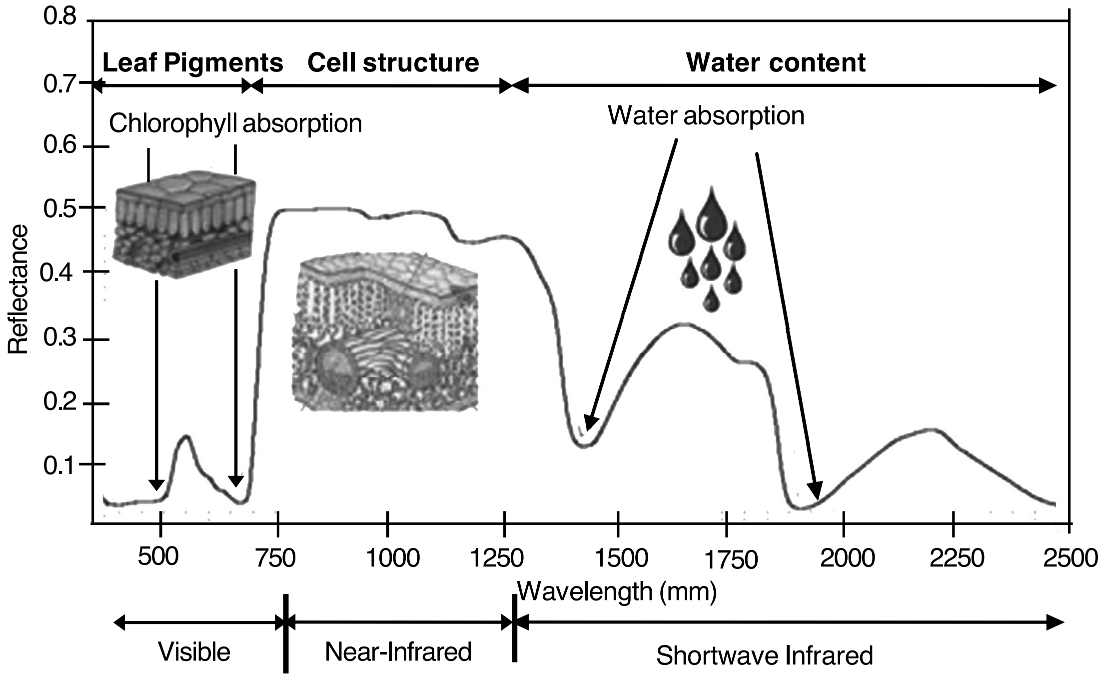

Fig 1: Typical spectra reflectance curve showing different regions of electromagnetic spectrum and major absorption features (Source: Prabhakar *et al.*, 2012)

Accurate quantification of early symptoms is important in pest management point of view, and efforts at remotely detecting plant stress due to disease or insect activity utilize principles of biophysical remote sensing (Jensen 1983). Plant stress usually results in an increase in visible reflectance (due to a decrease in chlorophyll and a resulting decrease in absorption of visible light), and a decrease in NIR reflectance from changes in the internal leaf structure (Hatfield and Pinter 1993). Use of remote sensing techniques for detection of insect pests and diseases of crop is based on the assumption that stresses induced by them interferes with photosynthesis and physical structure of the plant and affects the absorption of light energy and thus alter the reflectance spectrum of the plants (Riley 1989; Hatfield and Pinter 1993; Moran et al., 1997). Stress induction affects the physiological behaviour of plants, resulting in differences in reflectance patterns and thus

Types of Remote Sensing Platforms

Remote sensing platforms can be field-based (ground based), or mounted on aircraft (airborne) and satellites (space borne). Satellite RS is generally for large-scale study but it often cannot meet the requirement of spatial resolution in applications. Ground-based platform, such as hand-held spectroradiometer, is typically used for ground truth study. Airborne RS is flexible and able to achieve different spatial resolutions with different flight altitudes. Depending on the band width, number and contiguous nature of spectra recording spectral scanner scan be of two types viz., multispectral or broad band and hyperspectral or narrow band. Multispectral scanners sense several wavebands in a wider range of discrete wavelengths while hyperspectral scanners provide the opportunity to sense many very narrow wavebands over a wide range of wavelengths with much greater number of sensors. Multispectral systems measure energy in specific, strategically restricted portions of the electromagnetic spectrum while hyperspectral systems measure several consecutive wavebands across a specified region of the electromagnetic spectrum. However, a major limitation of broadband RS products is that they use average spectral information over broadband widths resulting in loss of critical information available in specific narrow bands. Recent developments in hyperspectral RS or imaging spectrometry have provided additional bands within visible, NIR and shortwave infrared (SWIR). Most hyperspectral sensors acquire radiance information in less than 10 nm bandwidths from the visible to the SWIR (400-2500 nm). For example, the spectral shift of the red-edge (670-780 nm) slope associated with leaf chlorophyll content, phenological state and vegetation stress, is not accessible with broadband sensors.

The data the RS sensors capture is often characterized by four kinds of resolutions viz., (i) spatial (the smallest resolvable unit is on the ground, also called the pixel), (ii) spectral (how sensitive the spectra is sampled), (iii) temporal (how often the data can be captured) and (iv) radiometric (the ability to discriminate very slight differences in reflected or emitted energy). The common pixel sizes are wide-ranging across different satellites. Weather satellites have pixel resolutions larger than 1 km; the AVHRR sensor, an early multispectral sensor still in use has a 1km pixel size; the series of Landsat sensor have 30 m pixels, and there are a range of newer commercial satellites (e.g. Quickbird and IKONOS) that have near and under 1 m spatial resolution. Sub-meter resolution imagery is increasingly common, especially with the use of aircraft-borne sensors. The spectral information contained in imagery can include multispectral (<10 bands of spectra, covering the visible and NIR portion of the spectrum), hyperspectral (10s to 100s of bands, covering a wider range of the spectrum) and thermal spectra (covering longer wave infrared emittance spectra).

Ground based remote sensing for pest damage

Spectro radiometry is the technique of measuring the spectrum of radiation emitted by a source. In order to do this the radiation must be separated into its component wavebands and each band measured separately. It is achieved by using a diffraction grating in spectroradiometers to split the radiation entering the system into its constituent wavebands. A suitable detector is then used to quantify the radiation of each wavelength. The field spectroscopy concerns measurement of the reflectance of composite surfaces in situ. Increasingly, spectral data are being incorporated into process-based models of the Earth's surface and atmosphere, and it is therefore necessary to acquire data from terrain surfaces, both to provide the data to parameterise models and to assist in scaling-up data from the leaf scale to that of the pixel. In most cases, the reflectance of a vegetation canopy or a soil surface is presented as a 'reflectance factor'.

Evidently, a limiting factor of ground based remote sensing is their applicability is for only for small areas when compared with aircraft and satellite sensors. However, using hand-held spectrometers to quantify the unknown spectral characteristics of uninfested and infested plant canopies due to insect feeding at a small-scale is needed because hand-held remote sensing devices have better temporal, spectral, and spatial resolutions, as well as the accuracy of collecting reûectance data over per unit area. Reûectance data obtained by hand-held instruments over small-areas provides information to understand spectral interactions between insect pests and their host plants, as well as fundamental ground-truth for interpretation of RS data measured from satellite and aircraft (Prabhakar *et al.*, 2013). Therefore, a logical initial step is to use a field spectrometer for understanding the spectral response of crop stress.

Airborne remote sensing for pest damage

Studies on the use of remote sensing for crop disease assessment started long time ago. For example, in the late 1920s, aerial photography was used in detecting cotton root rot. The use of infrared photographs was first reported in determining the prevalence of certain cereal crop diseases. In the early 1980s, Toler *et al* (1981) used aerial colour infrared photography to detect root rot of cotton and wheat stem rust. In these studies, airborne cameras were used to record the reflected electromagnetic energy on analogue films covering broad spectral bands. Since then, RS technology has changed significantly. Everitt *et al* (2003) provided an overview of aircraft remote sensing in integrated pest management with four exemplary examples viz., blackfly in citrus, silver whitefly in cotton, harvest ant infestations in rangelands and western pine beetle infestations in a forested area. They concluded that integration of remote sensing. GPS and GIS provide valuable tools that can enable resource managers to develop maps showing distribution of insect infestations over large areas. The digital imagery can serve as permanent data base for monitoring future contraction or spread of insect infestation over time. However, aircraft RS may suffer due to mismatching the image pixels with Russian wheat aphid spots on the ground for providing fundamental baseline data. Another possible drawback of airborne systems is the problem of spectral pixel mixing, which is the mixture of the signals from different objects such as soil, healthy and infested plants or vegetation, different species, and varying cover levels. Nevertheless, airborne multi-spectral imaging system has a great potential for use in area wide pest management systems.

Space borne remote sensing for pest damage

A large number of satellite remote sensing products are available at present. Each satellite has different spectral, spatial, temporal and radiometric resolutions and the choice of product depends on application. Some of the new satellites with multispectral and hyperspectral sensors on board are swiftly generating vast amounts of data in a cost-effective manner and at higher spatial and spectral resolutions. However, the use of these RS from satellite platform for detection of pests and diseases is limited owing to high spatial and temporal resolution of data required for this purpose. More so, availability of cloud free data during the crop season is another issue that limits us. al (1999) demonstrated that multispectral RS (MRS) would allow farmers to detect early infestation of mites in large scale cotton fields due to colour shifts and changes in canopy appearance over time. Areas identified on the map could be located with the help of portable GPS equipment by field scout, verify mite population in these areas and recommend regions in the field that require pesticide application. Nutter et al.(2002) used a combination of Landsat 7 and high spatial resolution multispectral imagery to map damage caused by soybean cyst nematode (*Heterodera glycines*). While other researchers have used Landsat (Nelson, 1983; Vogelmann and Rock, 1989; Goodwin *et al.*, 2008) and SPOT satellite imagery with coarse spatial resolutions to detect and assess insect damage to forests. It has been demonstrated that by the use of Landsat TM data it was possible to assess mountain pine beetle (*Dendroctonus ponderosae*) in western Canadabark beetle damage in pine forests. A spatial model has been developed using Landsat imagery and field observations based on environmental factors such as topography and soil types to predict densities of wheat aphid, *Diuraphis noxia* (Merrill *et al.*, 2009). Similarly using the same Landsat TM data, Mirk *et al.* (2011) separated healthy and streak mosaic diseased affected wheat fields by maximum likelihood classifier method with an overall classification accuracy of 89.47-99.07%. This method appears to be one of the best currently available for identification and mapping disease incidence over large and remote areas by offering a repeatable, inexpensive, and synoptic strategy during the course of a growing season.

Ji *et al.* (2004) evaluated the potential of MODIS data to monitor locust outbreaks in China and showed that the NDVI reliably distinguished between before and peak damage situations for each category of damage. Areas where NDVI decreased could be clearly mapped and classified into light, moderate, and heavy damage categories according to the decrease in their NDVI value. High resolution multi-spectral data from QuickBird were generally used to detect in-ûeld heterogeneities of crop vigour but are only moderately suitable for early detection of crop infections by diseases. However, QuickBird imagery was used for detecting citrus orchards affected by sooty mould and wheat diseases caused by powdery mildew (*Blumeria graminis*) and leaf rust (*Puccinia recondita*). A regional level spatial distribution model of aphid (*Lipaphis erysimi*) growth in Indian mustard using satellite based remote sensing data has been developed. They employed near surface meteorological parameters derived from National Oceanic and Atmospheric Administration (NOAA) Television and Infrared Operational Satellites (TIROS) Operational Vertical Sounder (TOVS) data and field observations of pest infestation. Second order polynomials fits were found at two locations tested in India i.e., Bharatpur and Kalyani between peak aphid count and TOVS cumulative air temperature at peak.

Case studies from India

The first successful application of remote sensing in India started with coconut wilt (Dakshinamurty, 1971). However, several workers have reported on its application for crop protection in different crops. Details are summarised below

Potato

Utility of ground-based hyperspectral data for detecting the potato late blight at early level of infestation was explored by Ray *et al.* (2011). The hyperspectral reflectance curves showed that healthy plants have high reflectance NIR region and low reflectance in red region. Once the disease intensity increases the NIR reflectance decreases and the red reflectance increases. The notable differences in healthy and diseased potato plants were noticed in 770–860 nm and 920–1050 nm range. The highest differences from healthy plants were recorded at highest level of infestation of 98% and it decreased with decrease in infestation. The eight best bands to discriminate between different disease intensities were 540, 610, 620, 700, 710, 730, 780 and 1040 nm. This included one band in green region, two in red region, three in red edge and two in infrared regions of the spectrum. Further analysis revealed a set of three bands (710, 720 and 750 nm) to discriminate between crops up to 25% of disease intensity (early detection).

In another study Dutta *et al.* (2014) an attempt has been made to discriminate healthy and late blight affected crop using space borne remote sensing-based indices such as Normalized Difference Vegetation Index (NDVI) and Leaf Surface Water Index (LSWI). Healthy and disease infected crop could be separated using the multi-date spectral profile of NDVI and LSWI indices. The NDVI values of normal healthy and diseased crops are almost same at 10 January, 2009 but it abruptly falls due to disease infestation as seen on January 29 and February 3, 2009. The fall in NDVI pattern manifests abrupt desiccation of crop canopy which is due to disease as crop is well irrigated with no scarcity of water. The dip in spectral profile is mainly due to disease incidence at the infected site as there was no scarcity of water in this fully irrigated region. Due to infection, internal structure of leaves get damaged and reduces water flow in plant which leads to increase in reflectance in short wave infra-red (SWIR) band. Deviation in LSWI was more prominent between the two dates as more soil exposure after infestation showed negative values compared to NDVI where the change was gradual. This reveals SWIR band can be effective band for potato late blight detection.

Chilli

An attempt has been made to discriminate healthy and thrips affected chilli crop in the multispectral satellite imagery using several multispectral spectral vegetation indices (Prabhakar *et al.*, 2019). A total of 51 fields were surveyed in predominantly chilli growing mandals during the *rabi* season of 2015-2016 in Mahabubnagar district, Telangana state. Sentinel 2A satellite data was used to calculate the spectral vegetation indices viz., Normalized Difference Vegetation Index (NDVI), Soil-adjusted Vegetation Index (SAVI), Land Surface Water Index (LSWI) and Normalized Difference Infrared Index (NDII) and Normalized Difference Water Index (NDWI). Performed independent t-test between different spectral vegetation indices of healthy and damaged crop, among the five spectral vegetation indices, only two indices viz., LSWI and NDWI were found more significant. This could be probably because these two indices are based on water content in the target. Whereas the other three indices viz., NDII, NDVI and SAVI are not directly related to moisture content, thereby their ability to discriminate thrips damage is not significant. Using this best performed indices, classified chilli fields into different categories of infestation (healthy, medium and severe).

Values of LSWI in the range of 0.04 to 0.18 has been classified as severe, whereas values between 0.18 to 0.24 and 0.24 to 0.50 were classified as medium and healthy, respectively. Whereas the NDWI values between 0.5 to 0.72, 0.4 to 0.52 and 0.2 to 0.4 were categorized as healthy, moderate and severe classes. The producer's accuracy of LSWI classified image showed that chilli healthy, moderate and severe infestation were to be 98.78, 89.46 and 86.27 %, respectively, and users' accuracy was found 55.39, 23.04 and 21.57 %, respectively. The error matrix indicates Kappa Coefficient is 0.89 and overall classification accuracy is 93.80%. Whereas, the producer's accuracy for NDWI classification of chilli healthy, moderate and severe infestation were found to be 91.50, 82.70 and 85.01 %, respectively and users' accuracy were found to be 91.33, 74.71 and 94.53 %, respectively. Based on the overall accuracy and Kappa coefficient values the LSWI was found to be superior compared to NDWI. Therefore, the LSWI was used to estimate area damaged by thrips and their infestation levels from the satellite imagery. The results showed that the chilli area under healthy was reduced from 2244.6 ha to 840.6 ha over a period of one month (10^{th} January and 9^{th} February 2016), mostly due to thrip damage. Whereas, the chilli area under medium and severe thrip damage categories was found increased from 174.28 ha to 807.48 ha and 215.04 ha 786.16 ha, respectively.

Rice

Prasannakumar *et al*. (2013) attempted to detect stress in rice plants grown in pots caused by the brown plant hopper (BPH), *Nilaparvata lugens*. BPH damage influenced reflectance of rice plants compared to uninfested plants in the visible and near-infrared regions of the electromagnetic spectrum. Correlations between plant reflectance and BPH damage when plotted against wavelengths, enabled us to identify four sensitive wavelengths at 1986 nm (r = 0.63), 665 nm (r = 0.58), 1792 nm (r = 0.53) and 500 nm (r = 0.52), in relation to BPH stress on rice plants. Based on rice plant reflectance corresponding to the sensitive wavelengths, three hyperspectral indices were developed. Regression analysis revealed a positive relationship between BPH damage level and BPH Index-1 ($r^2 = 0.65$, $P < 0.0001$), and a negative relationship for both BPH Index-2 ($r^2 = 0.67$, $P < 0.0001$) and BPH Index-3 ($r^2 = 0.78$, $P < 0.0001$). A multilinear regression model was developed between BPH damage levels and plant reflectance ($r^2 = 0.99$). The model was satisfactorily validated using a different data set for plant reflectance and BPH damage ($r^2 = 0.94$, RMSE = 0.79). The model can be used to predict BPH damage level based on plant reflectance at sensitive wavelengths (500, 665, 1792 and 1986 nm), which can be measured for an infested crop either at the field level or obtained through satellite imagery.

Severe incidence of brown plant hopper (BPH) in few villages of East Godavari (EG) district, Andhra Pradesh (A.P.) was identified through extensive field surveys during February-March, 2007 (Prabhakar *et al*., 2013). Ground based multispectral radiometric studies (CropScan16R) in rice showed spectral reflectance between 760-1100 nm could differentiate healthy and rice BPH infestation. Disease water stress index was found better than several other spectral vegetation indices for the early detection of rice BPH damage. IRS P6- LISS IV Mx satellite data was assessed to detect BPH damage in selected villages of EG district. NDVI values for BPH damaged pixels in the classified image were in the range of 0.1 to 0.2 compared to higher values for the healthy crop.

Cotton

Prabhakar *et al* (2011) has demonstrated the capability of remote sensing techniques for detection of leafhopper (LH) severity stress on cotton. Cotton plants with varying levels of LH severity were selected from three locations across major cotton growing regions of India. Selected about 57-58 cotton plants from each location exhibiting different levels of LH damage symptoms. Reflectance measurements in the spectral range of 350–2500 nm were recorded from selected plants using hyperspectral radiometer. In addition to spectral reflectance, chlorophyll (Chl) and relative water content (RWC) were also recorded from the selected plants. Reflectance from healthy and leafhopper infested plants showed a significant difference in VIS and NIR regions. Decrease in Chl a pigment was more significant than Chl b in the infested plants and the ratio of Chl a/b showed a decreasing trend with increase in LH severity. Regression analysis revealed a significant linear relation between LH severity and Chl ($r^2 = 0.505$), and a similar fit was also observed for RWC ($r^2 = 0.402$). Plotting linear intensity curves between reflectance at each waveband with infestation grade resulted in six sensitive bands that exhibited maximum correlation at different regions of the electromagnetic spectrum (376, 496, 691, 761, 1124 and 1457 nm). Regression analysis of several ratio indices formulated with two or more of these sensitive bands led to the identification of new leaf hopper indices (LHI) with a potential to detect leafhopper severity. These new indices along with 20 other stress related hyperspectral indices compiled from literature were further tested for their ability to detect LH severity. Two novel indices LHI 2 and LHI 4 proposed in this study showed significantly high coefficients of determination across locations (r^2 range 0.521 to 0.825) and have potential use for detection of leafhopper severity in cotton.

Prabhakar *et al*. (2013) conducted study to characterize reflectance spectra of cotton plants with

Table 1. Spatial and spectral characteristics different satellite sensors

Satellite/ Sensor	No of bands	Band width (μm)	Resolution	
			Spatial (meters)	Temporal (days)
Multi Spectral				
Landsat-1,2,3 MSS	4	0.5-0.6, 0.6-0.7, 0.7-0.8, 0.8-1.1	56 x 79	16
Landsat-4,5 TM	7	0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90, 1.55-1.75, 10.4-12.5, 2.08-2.35	30	16
Landsat-7 ETM+	8	0.52-0.90 (p)0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90, 1.55-1.75, 10.4-12.5, 2.08-2.35	1530	16
Landsat-8	11	0.50 - 0.68 (p) 0.43 - 0.45, 0.45 - 0.51, 0.53 - 0.59, 0.63-0.67, 0.85-0.88, 1.57-1.65, 2.11-2.29, 1.36-1.38, 10.6-11.19, 11.5-12.51	15 30	16
ASTER	14	VNIR: 3 bands (0.52-0.86) SWIR: 6 bands (1.6-2.43) TIR: 5 bands (8.125-11.65)	15 30 90	16
ALI	10	0.48-0.69 (p) VIS: 4 bands (0.433-0.69) NIR: 3 bands (0.775-1.30) SWIR: 2 bands (1.55-2.35)	10 30	16
SPOT-4	5	0.43-0.47, 0.50-0.59, 0.61-0.68, 0.79-0.89, 1.58-1.75	2.5-20	26
SPOT- 5				
-HRG	6	0.48-0.71 (p) 0.43-0.47, 0.50-0.59, 0.61-0.68, 0.79-0.89, 1.58-1.75	2.5 -5 10-20	26
-HRS	5	0.49-0.69 (p) 0.45-0.52, 0.61-0.68, 0.78-0.89, 1.58-1.75	5-10 1000	26
SPOT-6&7	5	0.45-0.745 (P) 0.45-0.52, 0.53-0.59, 0.625-0.695, 0.76-0.89	1.56 6	1
RESOURCESAT-2 (IRS-P6)				
-AWiFS	4	0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70	56	5
-LISS III	4	0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70	23	24
CBERS -2				
- CCD	5	0.51-0.73 (p), 0.45-0.52. 0.52-0.59, 0.63-0.69, 0.77-0.89	20	26
-IR MSS	4	0.50-1.10 (p), 1.65,2.22, 11.45	80-160	26
-WFI	2	0.66, 0.83 260	5	
NOAA- 14- AVHRR	5	0.58-0.68, 0.72-1.1, 3.55-3.93, 10.5-10.5, 11.5-12.5	1000	Daily
MODIS- TERRA	36	0.62 to 14.385	250-1000	Daily
Hyper Spectral				
EOS- Hyperion	196	VNIR- 427.55 to 925.85 nm (band 8 to 57) SWIR 932.72 to 2395.53 nm (band 79 to 224)	30	16

Satellite/ Sensor	No of bands	Band width (μm)	Resolution	
			Spatial (meters)	Temporal (days)
Hyper Spatial				
IKONOS	4	0.45-0.90 (p)0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90	14	5
QUICKBIRD	4	0.45-0.90 (p)0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90	0.612.40	5
RESOURCESAT- 2 LISS IV	3	0.52-0.59, 0.62-0.68, 0.77-0.86	5.8	5
Rapid Eye	5	0.44-0.51, 0.52-0.59, 0.63-0.68,0.69-0.73, 0.76-0.85	6.5	1-5.5
WorldView-4	5	450-800 (P)0.655-690, 0.51-58, 0.45-0.51, 0.78-0.92	0.311.24	Daily
CARTOSAT- 2	1	0.52- 0.85 (p)	1	5
FORMOSAT-2	5	0.45-0.90 (p) 0.45-0.52, 0.52-0.60, 0.63-0.69,0.76-0.90	2 8	Daily
KOMPSAT-3A	6	0.45-0.90 (p) 0.45-520, 0.52-0.60, 0.63-690, 0.76-0.90, 3.3-5.2	0.55 2.2 5.5	1.4
KOMPSAT-2	5	0.5-0.9 (p) 0.45-0.52, 0.52-0.6, 0.63-0.59, 0.76-0.90	1 4	14
ALOS-AVNIR-2	5	0.52-0.77 (p) 0.42-0.50, 0.52-0.60, 0.61-0.69, 0.76-0.89	2.5 10	2
Skysat-2	4	0.45-0.515, 0.515-0.595, 0.605-0.695, 0.74-0.90	0.8	4-5
SENITINEL-2A	13	0.443, 0.490, 0.560, 0.665, 0.705, 0.740, 0.783, 0.842, 0.865, 0.945, 1.375, 1.610, 2.190 (Central wavelength)		

(p): panchromatic

(Source: Prabhakar et al., 2012, modified)

Table 2. Spectral vegetation indices for pest and disease detection using remote sensing

S.No.	Index	Formula	Reference
1	Normalized Difference Vegetation Index (NDVI)	$(R_{800}- R_{670})/ (R_{800}+ R_{670})$	Rouse et. al., 1974
2	Red Edge Position (REP)	$700+40(RRE-R_{700})/(R_{740}-R_{700})$ $RRE= (R_{670}+R_{780})/2$	Guyot and Baret 1988
3	Chlorophyll Index (CI)	$(R_{415}-R_{435})/(R_{415} + R_{435})$	Barnes, 1992
4	Photochemical Reflectance Index (PRI)	$(R_{531}-R_{570})/ (R_{531}+R_{570})$	Gamon et. al., 1997
5	Simple Ratio (SR)	R_{695}/R_{420}	Carter, 1994
6	Normalized Pigment Chlorophyll Index (NPCI)	$(R_{680} – R_{430}) / (R_{680} + R_{430})$	Penuelas et. al., 1995
7	Structure insensitive vegetation index (SIPI)	$(R_{800}"R_{445})/(R_{800}+R_{680})$	Penuelas et al., 1995

S.No.	Index	Formula	Reference
8	Green Normalized Difference Vegetation Index (GNDVI)	$(R_{750} - R_{550})/(R_{750}+R_{550})$	Gitelson et. al. 1996
9	Optimized Soil-Adjusted Vegetation Index (OSAVI)	$(1+0.16)(R_{800} - R_{670})/(R_{800} + R_{670} + 0.16)$	Rondeaux et. al., 1996
10	Water index (WI)	R_{900}/R_{970}	Penuelas et al., 1997
11	Red-edge vegetation stress index (RVSI)	$(R_{714} + R_{752})/2"R_{733}$	Merton and Huntington, 1999
12	Modified Chlorophyll Absorption Reflectance Index (MCARI)	$[(R_{700} - R_{670})-0.2(R_{700} - R_{550})] (R_{700}/R_{670})$	Daughtry et. al., 2000
13	Transformed Chlorophyll Absorption Reflectance Index (TCARI)	$3 [(R_{700} - R_{670})-0.2(R_{700} - R_{550})$	Haboudane et. al., 2002
14	Ratio of TCARI and OSAVI	TCARI/OSAVI	Haboudane et. al., 2002
15	Browning Reflectance Index (BRI)	$(1/R_{550}-1/R_{700})/(R_{750})$	Chivkunova et al., 2001
16	Anthocayanin reflectance index (ARI)	$(R_{550})^{-1} - (R_{700})^{-1}$	Gitelson et. al., 2001
17	Zarco Tejada and Miller (ZTM)	R_{750} / R_{710}	Tejada et. al., 2001
18	Modified red edge normalized difference vegetation index (mNDVI705)	$(R_{750} - R_{705})/(R_{750} + R_{705} - 2*R_{445})$	Sims and Gamon, 2002
19	Disease Water Stress Index 2 (DWSI-2)	R_{1660}/R_{550}	Apan et. al., 2004
20	Damage Sensitive Spectral Index-2 (DSSI 2)	$(R_{747}- R_{901}-R_{537}-R_{572})/ (R_{747}- R_{901}) +(R_{537}-R_{572})$	Mirik et. al., 2006a
21	Aphid Index (AI)	$(R_{761}- R_{908})/(R_{712}- R_{719})$	Mirik et. al., 2006b
22	Broccoli soft rot index	$(D_{725}- D_{700})/(D_{725}+D_{700})$	Datt et. al., 2006
23	Bacterial lea spot index	$(R_{550}-R_{640})/ (R_{550}+R_{640})/$	Datt et. al., 2006
24	Sunburn Index	$(R_{450} - R_{680})/(R_{450} + R_{680})$	Datt et. al., 2006
25	Mealybug Stress Index-1 (MSI-1)	$(R_{550}+R_{768}+R_{1454})-[R_{1454}/(R_{550}+R_{768})]$	Prabhakar et. al., 2013
26	Mealybug Stress Index-2 (MSI-2)	$(R_{550}+R_{768})-(R_{1454}+R_{674})/ (R_{550}+R_{768})+ (R_{1454}+R_{674})$	Prabhakar et. al., 2013
27	Mealybug Stress Index-3 (MSI-3)	$(R_{550}-R_{674})/(R_{550}+R_{674})$	Prabhakar et. al., 2013
28	Leaf Hopper Index-1 (LHI-1)	(R_{691}/R_{761})	Prabhakar et. al., 2011
29	Leaf Hopper Index-2 (LHI-2)	$(R_{1124}-R_{691})/(R_{1124}+R_{691})$	Prabhakar et. al., 2011
30	Leaf Hopper Index-3 (LHI-3)	$(R_{761}-R_{691})/(R_{761}+R_{715})$	Prabhakar et. al., 2011
31	Leaf Hopper Index-4 (LHI-4)	$(R_{761}-R_{691})/(R_{550}-R_{715})$	Prabhakar et. al., 2011
32	Land Surface Water Index (LSWI)	$(R_{nir}-R_{swir})/(R_{nir}+R_{swir})$	Xiao et al., 2004
33	Normalized Difference Water Index (NDWI)	$(R_{858}-R_{2130})/(R_{858}+R_{2130})$	Gu et al., 2007

R : Reflectance at corresponding nm; D: First order derivative at corresponding nm

known mealybug infestation levels (grade-0 is healthy and grade-4 is severe), and seek to identify specific narrow wavelengths sensitive to mealybug damage. Reflectance measurements were made in the spectral range of 350–2500 nm using a hyperspectral radiometer. Significant differences were found in green, near infrared and short wave infrared spectral regions for plants with early stages of *P. solenopsis* infestation, and for plants showing higher grades of infestation these differences extended to all the regions except blue. A significant reduction in total chlorophyll (12.83–35.83%) and relative water content (1.93–23.49%) was observed in the infested plants. Reflectance sensitivity analysis of the hyperspectral data revealed wavelengths centered at 492, 550, 674, 768 and 1454 nm as most sensitive to mealybug damage. Mealybug Stress Indices (MSIs) were developed using two or three wavelengths, tested using multinomial logistic regression (MLR) analysis and compared with other indices published earlier. Results showed that the MSIs were superior ($r^2 = 0.82$) to all other spectral vegetation indices tested. Further, the proposed MLR models corresponding to each MSIs were validated using two independent field data sets. The overall percent correct classification of cotton plants into different mealybug damage severity grades was in the range of 38.3 and 54.9. High classification accuracy for grade-1 (81.8%) showed that models are capable of early detection of mealybug damage.

Blackgram

Prabhakar *et al* (2013) attempted rapid and non-destructive estimation of Yellow mosaic disease (YMD) by hyperspectral remote sensing. Field studies were conducted for two seasons with eight blackgram genotypes having differential response to YMD. Comparison of mean reflectance spectra of the healthy and YMD infested leaves showed changes in all the broad band regions. However, reflectance sensitivity analysis of the narrow-band hyperspectral data revealed a sharp increase in reflectance from the diseased leaves compare to healthy at 669 (red), 505 and 510 nm (blue). ANOVA showed a significant decrease in leaf chlorophyll ($p < 0.0001$) with increase in disease severity, while no such relationship was observed for relative water content. By plotting coefficients of determination (r^2) between leaf chlorophyll and percent reflectance at one nm wavelength interval, two individual bands (R571; R705) and two band ratios (R571/R721; R705/R593) with highest R^2 values were selected. These bands showed a significant linear relationship with SPAD chlorophyll readings (r^2 range 0.781 – 0.814) and spectrometric estimates of total chlorophyll content (R^2 range 0.477 – 0.565). With optimal spectral reflectance ratios as inputs, disease prediction models were built using multinomial logistic regression (MLR) technique. Based on model fit statistics, reflectance ratios R571/R721 and R705/R593 were found better than the individual bands R571 and R705. Validation of MLR models using an independent test data set showed that the overall percentage of correct classification of the plant into one of the diseased categories was essentially same for both the ratios (68.75%). However, the MLR model using R705/R593 as dependent variable was of greater accuracy as it gave lower values of standard errors for slopes ($\hat{a}_G$ range 9.79–36.73) and highly significant estimates of intercept and slope ($p < 0.05$). Thus, the models developed in this study have potential use for rapid and non-destructive estimation of leaf chlorophyll and yellow mosaic disease severity in blackgram.

Sorghum

Prabhakar *et al* (2021) studied on fall armyworm (FAW) Damage on sorghum from the farmers' fields of southern India was assessed using space-borne data. Comparison of the Sentinel-2A satellite data of pre and post infestation periods revealed reduction in Leaf Area Index (LAI) in the infested fields. Groundtruth data confirmed that FAW infestation reduced LAI by 49.7%, biomass by 32.5% and grain yield by 51.8%. Infestation at Panicle Initiation (PI) stage caused maximum yield loss compared to flag leaf visible and boot stages. The interaction results showed FAW infestation at different crop stages had significant effect on biomass and yield, but not on LAI. Regression analysis with spectral vegetation indices revealed LAI (r^2: 0.82) and NDVI (r^2: 0.80) were significantly superior in identifying FAW infestation from the satellite data.

Singh *et al* (2007) studied on grasshopper in forage variety of sorghum (Meethi Sudan). The beds of crop sorghum were specially prepared for pests as well as microwave scattering measurements. In first phase of study, plant parameters observed and analyzed and it was noticed that pests were more dependent on sorghum chlorophyll than other plant parameters, while climatic conditions were taken as constant. An empirical relationship has been developed between occurrence of pests and TC with quite significant values of coefficient of determination (r^2 = 0.82). In the second phase of this study, several observations were carried out for various growth stages of sorghum using scatterometer for both like polarizations (i.e., HH- and VV-) and different incidence angles at X-band (9.5 GHz). Linear regression analysis was carried out to obtain the best suitable incidence angle and polarization to assess the sorghum TC. VV-pol gives better results than HH-pol and incidence angle should be more than 40° for both like polarizations for assessing the sorghum TC at X-band. A negative correlation has been obtained between TC and scattering coefficient with the r^2 values (0.69 and 0.75 for HH- and VV-pol, respectively). The TC assessed by the microwave measurements was helpful to estimate the occurrence of pests on sorghum. Based on both phase of study an algorithm is proposed to estimate the number of pest on sorghum by remote sensing method.

Soyabean

Gazala *et al* (2013) examined spectral reflectance of soybean leaves due to Mungbean yellow mosaic India virus (MYMIV) infection in order to identify YMD sensitive spectral reflectance. Spectral reflectance measurement indicated significant ($p < 0.001$) change in reflectance in the infected soybean canopy as compared to the healthy one. In the infected canopy, reflectance increased in visible region and decreased in near infra-red region of spectrum. Reflectance sensitivity analysis indicated wavelength 642nm, 686nm and 750 nm were sensitive to YMD infection. Whereas, in yellow leaves induced due to nitrogen deficiency, the sensitive wavelength was 589 nm. Due to viral infection, a shift occurred in red and infra-red slope on the left in comparison to healthy one. Red edge shift was a good indicator to discriminate yellow mosaic as chlorophyll gets degraded due to MYMIV infection. Correlation of reflectance at 688 nm (R688) and spectral reflectance ratio at 750nm and 445 nm (R750/R445) with the weighted mosaic index indicated that detection of yellow mosaic is possible based on these sensitive bands.

Das *et al* (2013) conducted field experiment on yellow mosaic virus infected soybean leaves. Normalized Difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Greeness Index (GI), Photochemical Reflectance Index (PRI) and Leaf Moisture Vegetation Index 1 (LMVI1) were computed and it was observed that NDVI was found to be useful in detecting yellow mosaic virus infected soybean.

Safflower

The study (Prabhakar *et al*., 2012) demonstrated the utility of ground based hyperspectral remote sensing for assessing certain biotic and abiotic traits associated with safflower. Experiment was conducted with 8 cultivars grown under three depths. Results showed that Normalised Pigment to Chlorophyll Index (NPCI) had highest correlation (r=0.78) with the measured chlorophyll. Regressing the NPCI upon measured chlorophyll resulted in a linear functional relationship (R^2 = 0.6086, p < 0.0001), when validated with independent data set showed promising results. NDVI and LAI measured during flower initiation stage showed strong relation with dry matter, biomass and seed yield. Mean reflectance spectra between healthy and *Allernaria* diseased plants showed a distinct separation of bands in visible, NIR and SWiR regions. Among several hyperspectral Indices tested, Red edge Normalised Difference Vegetation Index, Normalised Pigment Chlorophyll Index and Normalised Difference Vegetation Index were found superior for detection of *Allernaria* disease at early stages of infection.

CONCLUSION

Remote sensing gives a synoptic view of the area and it can supplement many of the on-going field surveillance programs, which are time consuming, laborious and some times error prone. Remote sensing technology is reliable and provides accurate information to guide decision-making in crop pest management. Extensive studies have been carried out world over for characterizing biotic stress using ground-based radiometry (multi and hyperspectral). Hyperspectral radiometry provides more details and would help to have a better understanding of the crop stress induced by pests and diseases. Further, the ground based radiometric studies provide key information to understand spectral interactions between pests damage on the plants. Also, such ground-truth data is essential to interpret air/ space borne remote sensing data. Satellite remote sensing provides sufficient data for large scale studies, but it has limitations such as temporal and spatial resolution and cloud cover. Small farm holdings and diverse cropping systems in countries like India further make their use complicated. Airborne systems have a higher resolution and time ûflexibility and provide sufficient lead time for dissemination of crop protection advisory compared to space borne data. But airborne remote sensing is widely used only in developed nations owing to high cost and also difficulty in acquiring data due to several reasons. The narrow bands in the hyperspectral remote sensing are able to measure the characteristic absorption peaks of plant pigments more precisely and thereby provide better information related to plant health. But availability of hyperspectral data from satellite platforms is only to a limited extent. In this context, the future of use of remote sensing in agriculture in general and in pest management in particular depend on making Unmanned aerial vehicles (UAV), popularly known as drones. There is need for more research efforts to identify pest/ disease specific sensitive bands at narrow wave bands (hyper spectral), spectral vegetation indices (SVI), image acquisition, analysis and interpretation of data from UAV platforms. Effective use of IOT, artificial intelligence (AI) and big data analytics, integrated with remote sensing technologies would become a rapid and effective tool that provide information on spatial variability of pest infestations in real time. This would eventually help in guided field scouting for identifying pest infestation from large areas, that would save time, resources and enable for area-wide past management in future.

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Research Article
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VIRULENCE OF RICE BROWN PLANTHOPPER, *Nilaparvata lugens* (Stsl) POPULATION FROM KHAMMAM DISTRICT OF TELANGANA STATE AGAINST RICE GENOTYPES AND ITS MORPHOMETRICS

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ABSTRACT

Thirty two rice genotypes with known and unknown genetics were evaluated for their resistance reaction to rice brown planthopper (BPH) *Nilaparvata lugens* (Stål) population collected from Khammam district of Telangana state, India by Standard seedbox Screening method at ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad during 2018-19. Four genotypes *viz.*, PTB 33 (Bph2, Bph3 and Bph32 genes), RP 2068-18-3-5 (Bph33t + gene), RP Bio 4918-230S (bph39 and bph40 genes) and IR 62 (Bph3 gene) were found resistant with a damage score of 1.1-3.0. Two genotypes *viz.*, MTU 1010 and Sinnasivappu with unknown genetics were moderately resistant. The other genotypes were susceptible to Khammam BPH population. The resistant genotypes can be used in the breeding programme to develop brown planthopper resistant varieties for that region. The morphometrics i.e total body length and width, abdominal length and width, length of rostrum, length of tibial spur, antennal length, interocular distance of five nymphal instars (1st, 2nd, 3rd, 4th and 5th), winged (macropterous), wingless (brachypterous) females and males were recorded. In case of macropterous and brachypterous adults the length and width of wing were also measured. The females measured from 2.6 mm to 3.2 mm and the males measured from 1.9 to 2.3 mm in length. The length of tibial spur was 0.29 to 0.35 mm and that of rostrum was 0.86 mm in males and 1.19 mm in females. The nymphal instars increased in body length from 1.19 mm (1st instar) to 3.3 mm (5th instar).

Rice (*Oryza sativa*) is one of the agronomically and nutritionally important cereal crop in developing countries and it is the principal staple food grain in India. Brown planthopper (BPH) *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), is one of the serious sucking insect pests. BPH is a phloem sap sucking insect pest which affects the growth of rice plants and results in "hopper burn" (Watanabe and Kitagawa, 2000). It is also a vector, transmitting viral diseases such as grassy stunt and ragged stunt (Khush and Brar, 1991; Jena *et al.*, 2006). Chemical control is the principal method of controlling BPH but indiscriminate use of chemicals leads to environmental hazards. Host-plant resistance is the most desirable and economic strategy for the control of BPH (Vanisri *et al.*, 2020). Till date, forty BPH resistance genes have been identified from rice cultivars. Resistant and moderately resistant varieties keep the pest densities below economic threshold levels. The BPH resistance genes from *Bph1* to *Bph 9, Bph19*, *Bph 25*, *Bph 26*, *Bph 28*, *Bph 31-Bph 33, Bph 33*(t) (Naik *et al.*, 2018), *Bph 37, Bph 38* are from cultivated rice, *O. sativa* as gene source, whereas *Bph10* to *Bph18, Bph 20 to Bph 24* and *Bph 27 to Bph 31(t), Bph 34 to Bph 36* and *Bph 39(t)* and *Bph 40(t)* (Akanksha *et al.*, 2019) are from wild rice species. Due to lack of precise studies under controlled conditions, information on performance of identified sources of BPH against various BPH populations across India in general and Telangana state in particular is lacking. Hence, an attempt was made to study the response of thirty gene differentials against BPH population collected from Khammam district of Telangana state, India which is endemic to BPH.

Morphometric techniques have proven to be useful in separating morphologically similar groups in the absence of any other diagnostic characters (Claridge 1983). A closer look at the brown planthopper populations showed not only the insects differ in their response to the resistance factors in the rice plant but differences in morphological appearances were also observed (Saxena and Rueda 1982). Geometric Morphometrics (GM) has recently become a popular tool in many fields of biology including systematics, ecology or anthropology as it affords new possibilities for the interpretation of shape and shape change in

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organisms. We have studied the morphometrics of BPH population of Khammam district of Telangana state.

MATERIAL AND METHODS

Mass rearing of brown planthopper collected from Khammam district

BPH population were collected from rice fields of Aswaraopet, Wyra, Narayanapuram and Maddikonda mandals of Khammam district of Telangana state by following the methodology as described by Nagendra Reddy (2016) and the insects and infested hills were brought to ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad during the year 2018. The filed collected BPH population was mass reared on the susceptible rice variety, TN1. Pure BPH culture was maintained in the glasshouse at a temperature of 30$\pm$ 5°C with relative humidity of 70$\pm$5% on 60 day old potted plants of TN1. Mass rearing was done in cages of 70 cm x 62 cm x 75 cm dimension glass panels on one side and wire mesh on all other sides. Twenty adult gravid female hoppers were collected with an aspirator and were released on pre-cleaned potted plants of TN1 and are placed in oviposition cages. After four days of egg-laying, the gravid females were collected and released on fresh batch of TN1 plants for further egg laying. Plants with eggs were taken out of cages and placed in separate cages for the nymphs to hatch. Fresh plants were placed in the cages with nymphs as and when required. The hatched nymphs were utilized for experiments as and when they attained the desired age.

Mass Screening of the genotypes

Thirty rice genotypes were mass screened for resistance to brown planthopper collected from Khammam district of Telangana state in greenhouse using standard seed box screening test Kalode *et al.* (1975) on 0-9 scale at ICAR- Indian Institute of Rice Research, Rajendranagar, Hyderabad. The method involved infestation of young seedlings (about 12 days old) of test entries grown in screening trays (50cm x 40cm x 8cm) filled with fertilizer enriched puddled soil. Each screening tray included 20 test lines with about 15-20 seedlings per line; one row of resistant check (Ptb 33) in the middle and two rows of susceptible check TN1 in the borders. After sowing, the screening trays were placed in fibre trays (60cm x 180cm x 8cm) filled with water and were covered with mylar cages when the plants were 12-13 days-old to prevent escape of the nymphs. First and second instar nymphs of BPH were released on the seedlings ensuring that each test seedling was infested with at least 6-8 nymphs. The infested trays were monitored regularly for plant damage. When TN1 plants on one side showed damage, the tray was rotated by 1800 for even reaction on both the sides. When more than 90 per cent plants in the susceptible check (TN1) were killed, the test entries were scored for the damage reaction based on the 0-9 scale of International Standard Evaluation System (IRRI, 2013) and damage reaction was given according to Kalode *et al.*, 1975 (Table 1). All the genotypes were screened in two replications.

Different morphological parameters of brown planthopper like total body length, total body width, length of abdomen, width of abdomen, length of wing, width of wing, antennal length, inter ocular distance, length of tibial spur and length of rostrum of all five nymphal instars as well as both forms of females and males (macropterous and brachypterous) of adult brown planthoppers have also been recorded under stereo zoom binocular microscope.

Table 1. Classification of resistance based on damage reaction

Plant State	Damage Score	Resistance classification
None of the leaves yellow or dead	0	Highly resistant (0.0-1.0)
One bottom leaf yellow	1	Resistant (1.1-3.0)
One or two leaves yellow or leaf dried	3	Moderately resistant (3.1-5.0)
One or two leaves dried or one leaf healthy	5	Moderately susceptible (5.1-7.0)
All leaves dried or yellow but stem green	7	Susceptible (7.1-8.9)
Plant dead	9	Highly susceptible (9.0)

RESULTS AND DISCUSSION

Reaction of gene differentials

Out of the thirty gene differentials screened, four gene differentials *viz.*, PTB 33 (DS 1.5), RP 2068-18-3-5 (DS 2.1), RP Bio 4918-230S (DS 2.5) and IR 62 are resistant with a damage score of 1.1-3.0 to brown planthopper population of Khammam district (Table 2). Two gene differentials *viz.*, MTU 1010 (DS 4.9), Sinasivappu (DS 3.6) are moderately resistant with a damage score of 3.1-5.0. Nine gene differentials *viz.*, Mudgo (DS 6.9), T12 (DS 6.7), OM 4498

Table 2. Resistance reaction of rice genotypes to Khammam BPH population

S. No	Genotypes	Genes	Damage score	Resistance reaction
1	Mudgo	Bph1	6.9	MS
2	IR 64	Bph1+	7.8	S
3	ASD 7	bph2	8.5	S
4	Milyang 63	Unknown	8.7	S
5	Rathuheenathi (ACC1)	Bph3+Bph17	8.6	S
6	Babawee	bph4	8.9	S
7	ARC 10550	bph5	8.7	S
8	Swarnalatha	Bph6	7.9	S
9	T 12	bph7	6.7	MS
10	Chinasaba	bph8	8.2	S
11	Pokkali	bph9	7.3	S
12	IR 65482-7-216	Bph18	8.7	S
13	IR 71033-121-15	BPH20/21	7.7	S
14	MUT NS1	Unknown	8.1	S
15	OM 4498	Unknown	6.2	MS
16	RP 2068-18-3-5	Bph33t+	2.1	R
17	MO 1	Unknown	7.1	S
18	MTU 1010	Unknown	4.9	MR
19	RP BIO 4918-230S	bph39 and bph40	2.5	R
20	IR 26	Bph1	6.9	MS
21	IR 40	bph2	6.6	MS
22	IR 66	Bph4	6.1	MS
23	IR 72	Bph3	6.9	MS
24	Utrirajappan	Unknown	9.0	HS
25	Ndiang Marie	Unknown	5.7	MS
26	Sinnasivappu	Unknown	3.6	MR
27	Balamawee	Bph9	8.5	S
28	IR 62	Bph3	2.3	R
29	Rathuheenathi (ACC2)	Bph3+Bph17	6.0	MS
30	IR 65482-4-136-2-2	Bph18	8.4	S
31	PTB 33	Bph2, Bph3 & Bphh32	1.5	R
32	TN1	None	9.0	HS

R= Resistant; MR= Moderately Resistant; S= Susceptible; MS= Moderately Susceptible;
HS= Highly Susceptible

(DS 6.2), IR 26 (DS 6.9), IR 40 (DS 6.6), IR 66 (DS 6.1), IR 72 (DS 6.9), Ndiang Marie (DS 5.7), Rathuheenathi (ACC2) (DS 6.0) were moderately susceptible with a damage score of 5.1-7.0.

Fifteen gene differentials *viz.*, MO 1 (DS 7.1), IR 64 (DS 7.8), ASD 7 (DS 8.5), Milyang 63 ((DS 8.7), Rathuheenathi (ACC1) (DS 8.6), Babawee (DS 8.9), ARC 10550 (DS 8.7), Swarnalatha (DS 7.9), Chinsaba (DS 8.2), Pokkali (DS 7.3), IR 65482-7-216 (DS 8.7), IR 71033-121-15 (DS 7.7), MUT NS1 (DS 8.1), Balamawee (DS 8.5), IR 65482-4-136-2-2 (DS 8.4) were susceptible. One gene differential Utrirajappan with unknown genetics along with susceptible check TN1 was highly susceptible to brown planthopper population of Khammam district.

Screening for resistance against brown planthopper, *N. lugens* is a continuous process to identify new sources of resistance to the pest to combat the problem of biotypes and also to find out sources with multiple resistances. International Rice Research Institute (IRRI) has initiated screening of thousands of rice varieties and lines including worldwide germplasm collections and breeding lines of rice in which a large number of varieties were identified as resistant (IRRI, 1979; Kaneda and Kisimoto, 1979. In India, host plant resistance to BPH is being exploited in several research centres and important sources of resistance have been identified (Reddy *et al.*, 2003; Saxena and Saxena, 2006; Alagar *et al.*, 2007; Ramdeen *et al.*, 2010; Jhansi Lakshmi *et al.*, 2010; Ramulamma *et al.*, 2015; Nagendra Reddy *et al.*, 2016; Sunil *et al.*, 2018; Naik *et al.*, 2018; Anupama *et al.*, 2019). Identification of resistant donors and their use in breeding programme has been attempted by earlier workers (Akanksha *et al.*, 2019). The results are in conformity with Akshaya 2011, Sunil *et al.*, 2018 and Akanksha *et al.*, 2019 who observed that RP Bio 4918-230S derived from Swarna X *Oryza nivara* was highly resistant in glasshouse and with 10% hopperburn in field whereas MO1 showed susceptibility. Lakhan dhar, 2008 and Sunil *et al.*, 2018 observed that RP 2068-18-3-5 was resistant with damage score of 1.4. Nagendra Reddy *et al.*, 2016a, Ramulamma *et al.*, 2015 and Anupama *et al.*, 2019 reported that PTB 33 was resistant to brown planthopper.

Morphometrics of brown planthopper population of Khammam

Morphometrics of brown planthopper adults and nymphs collected from Khammam district of Telangana were presented in Table 3 and figure 1.

Macropterous females

The total body length of macropterous BPH adult female was 2.617 mm and body width was 1.063 mm. The length and width of wing were 3.227 mm and 0.715 mm respectively. Length of antennae was 0.877 mm and the inter ocular distance was 0.280 mm. Length of tibial spur and the rostrum were 0.301mm and 1.191mm respectively.

Brachypterous females

The body length of adult brachypterous female was 3.210 mm and width of the body was 1.202 mm. Length and width of the wing were 1.632 mm and 0.801 mm respectively. The length of antennae was 1.049 mm and inter ocular distance was 0.291 mm. Length of tibial spur was 0.294 mm and Length of rostrum was 0.983 mm.

Macropterous male

The length and width of the body of adult macropterous male BPH were 2.316 mm and 1.023 mm respectively. Length of the wing was 3.060 mm and width was 0.602 mm. Length of antennae and inter ocular distance were 0.940 mm and 0.255 mm respectively. Tibial spur length was 0.353 mm and length of rostrum was 0.852 mm.

Brachypterous male

The body length and body width of brachypterous male were 1.995 mm and 1.202 mm respectively whereas the length and width of wing were 1.194 mm and 0.595 mm respectively. The length of antennae, inter ocular distance, tibial spur and rostrum were 0.943 mm, 0.268 mm, 0.340 mm and 0.863 mm respectively.

BPH nymphs

The length of the 1st, 2nd, 3rd, 4th and 5th nymphal instars was 1.198 mm, 2.179 mm, 2.628 mm, 3.052 mm and 3.323 mm respectively while the width of the respective instars was 0.466 mm, 0.867 mm, 1.081 mm, 1.183 mm and 1.245 mm. Length of antennae of respective instars was 0.474 mm, 0.782 mm, 0.860 mm, 0.741 mm and 0.877 mm and interocular distance

Table 3. Morphometrics of Khammam brown planthopper adults

Insect Forms	Measurements in Millimetres									
	Body length	Body width	Abdominal length	Abdominal width	Antennal length	Inter-ocular distance	Length of tibial spur	Length of rostrum	Length wing	Width of wing
Macropterous Male	2.316 ±0.24	1.023 ±0.02	1.333 ±0.02	0.992 ±0.05	0.940 ±0.01	0.255 ±0.03	0.353 ±0.03	0.852 ±0.09	3.060 ±0.1	0.602 ±0.09
Brachypterous Male	1.995 ±0.13	1.051 ±0.03	1.350 ±0.02	1.007 ±0.03	0.943 ± 0.02	0.268 ± 0.03	0.340 ±0.03	0.863 ±0.07	1.194 ±0.21	0.595 ±0.05
Macropterous Female	2.617 ±0.20	1.063 ±0.07	2.198 ±0.15	0.933 ±0.11	0.877 ±0.09	0.280 ±0.03	0.301 ±0.09	1.191 ±0.16	3.227 ±0.11	0.715 ±0.11
Brachypterous Female	3.210 ±0.29	1.202 ±0.03	1.828 ±0.27	1.395 ±0.22	1.049 ±0.09	0.291 ±0.04	0.294 ±0.05	0.983 ±0.04	1.632 ±0.39	0.801 ±0.06

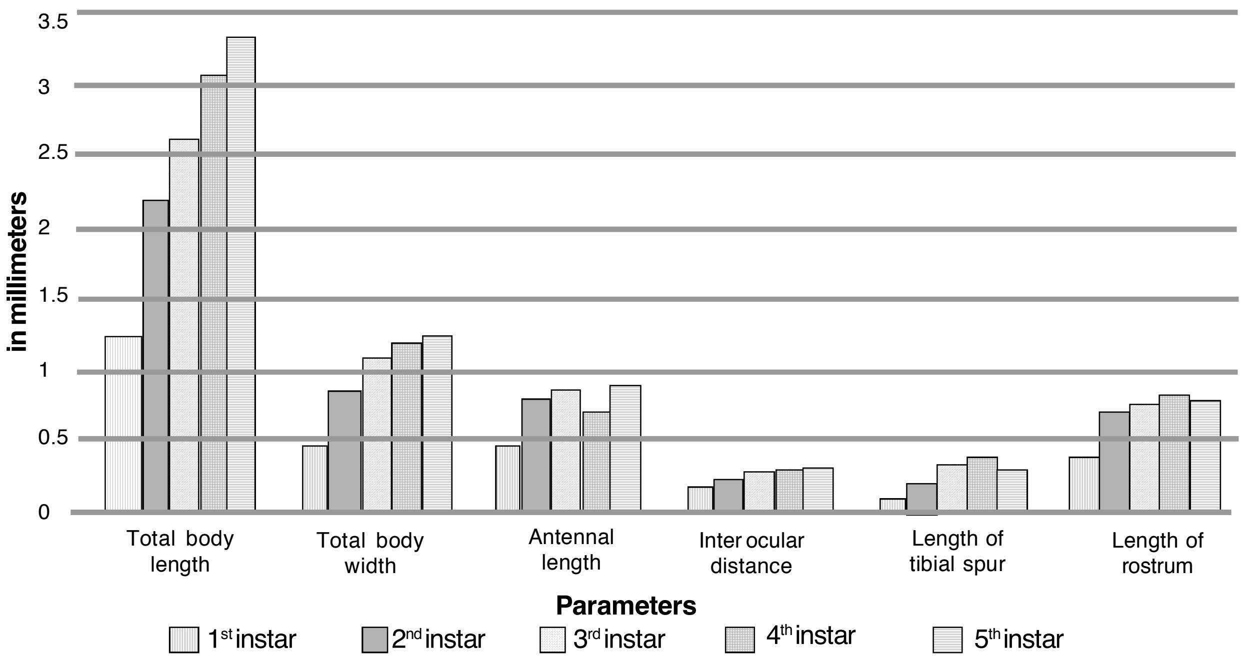

Fig 1. Morphometrics of nymphal instars of brown planthopper

was 0.177 mm, 0.231 mm, 0.254 mm, 0.272 mm and 0.271 mm. Length of tibial spur for 1st instar was 0.082 mm, for 2nd instar was 0.181 mm, for 3rd , 4th and 5th instars were 0.290 mm, 0.317 mm and 0.272 mm respectively. Rostrum length for respective 1-5 instars was 0.346 mm, 0.717 mm, 0.765 mm, 0.797 mm and 0.760 mm.

According to Cook and Perfect (1982), the adult forewing length in *N. lugens* macropterous male is 3.0-3.2 mm, in brachyptrous male is 1.0 -1.6 mm, in macroptereous female is 3.0-3.8 mm and brachypterous female is 1.1- 1.6 mm. Similar morphometrical studies were conducted by Bhattacharyya *et al.* (1983) on macropterous forms of Pantnagar and Hyderabad populations.

CONCLUSION

In the present study four rice gene differentials *viz.*, PTB 33, RP 2068-18-3-5, RP Bio 4918-230S and IR 62 were found resistant against Khammam brown planthopper population which can be used in the breeding programme to develop brown planthopper resistant varieties. The morphological parameters of brown planthopper of Khammam district can pave way to differentiate Khammam brown planthopper population from the BPH populations of other districts of Telangana state.

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Research Article
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EFFECT OF DIFFERENT SOWING DATES AND IRRIGATION SCHEDULES ON YIELD, WATER-USE EFFICIENCY AND ECONOMICS OF MAIZE (*Zea mays* L.)

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ABSTRACT

Field experiment was conducted at Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif* 2016 and *rabi* 2016-17 with four dates of sowing (18 June, 4 July, 19 July and 10 August) and four irrigation regimes (I_0: Control (Rainfed); I_1: 0.4 IW/CPE; I_2: 0.6 IW/CPE and I_3: 0.8 IW/CPE) in *kharif* 2016. On similar lines the trial was conducted with four dates of sowing (1 November, 18 November, 1 December and 17 December) and four irrigation regimes (I_1: 0.4 IW/CPE; I_2: 0.6 IW/CPE; I_3: 0.8 IW/CPE and I_4: 1.0 IW/CPE) in *rabi* 2016-17. Among different dates of sowing, highest number of rows cob^{-1} (15.3, 13.2), number of grains row^{-1} (24.4, 22.5), test weight (30.2, 26.8 g) and grain yield (6963, 5396 kg ha^{-1}) were recorded with 4 July (D_2) and 1 November (D_1) sown crops during *kharif* 2016 and *rabi* 2016-17 respectively. Out of irrigation regimes tested, highest number of rows cob^{-1} (14.5, 14.8), number of grains row^{-1} (25.5, 25.2), test weight (28.5, 28.9 g) and grain yield (6369, 7105 kg ha^{-1}) were observed at 0.8 IW/CPE (I_3) and I_4 (1.0 IW/CPE) during *kharif* 2016 ε₹d *rabi* 2016-17 respectively. Across different sowing dates, significantly higher WUE (13.0, 13.2 kg ha-mm^{-1}), net returns (70260, 47209 ha^{-1}) and B:C ratio (2.06, 1.32) were noticed with 4 July (D_2) and 1 Novembı₹ (D_1) sown crops in *kharif* 2016 and *rabi* 2016-17 respectively. Among irrigation schedules, significantly higher net returns (61476, 72056 ha^{-1}) and B:C ratio (1.79,1.99) was recorded with I_3 (0.8 IW/CPE) and I_4 (1.0 IW/CPE) in *kharif* 2016 and *rabi* 2016-17 respectively.

Among cereals, maize is grown throughout the year mainly due to its photo-thermo-insensitive character, hence called 'queen of cereal'. In India, maize is the third most important cereal crop after rice and wheat. Maize crop growth is affected by different stresses *viz.,* water, pest, weed, nutrients, etc., which reduce the productivity. Radiation (light), temperature and soil moisture are the major environmental factors which determine growth and productivity of any crop. Scarcity of water is the most common adverse environmental condition that can affect crop growth and development and can cause a substantial loss of crop yield (Eck, 1986; Lamm *et al*., 1994). Since development rate and duration of phenological stages were largely determined by prevailing temperatures, identification of optimum sowing time is one of the very important factors to obtain optimum productivity. Rainfall is erratic and meager during *kharif* season and hence irrigation water quantity and intervals play a great role to grow the crop successfully (Stone *et al.,* 2001; Igbadun *et al.,* 2008; Kumar *et al.,* 2013; Dobermann *et al.,* 2011; Painyuli *et al.,* 2013 and Reddy *et al.,* 2013) and in *rabi* irrigation plays a crucial role. Hence finding out good water management strategy and identification of proper sowing window for the crop to utilize synthetic active radiation (PAR) are still promising management recommendation in order to increase productivity of maize during both the seasons (Kar *et al.,* 2005) in any region. Therefore, the present investigation was carried out with an objective to study the effect of different dates of sowing and irrigation management during both the seasons to maximize grain yield and water use efficiency.

MATERIAL AND METHODS

The field experiment was conducted at Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad having 17.019' N Latitude, 78.023' E Longitude and 542.3 m above mean sea level. The soil of the experimental site was sandy loam in texture, neutral in reaction, low in available nitrogen, phosphorus and high in available potassium. The experiment was conducted during *kharif* 2016 and *rabi* 2016-17 in split-plot design with four dates of sowing (18 June, 4 July, 19 July and 10 August /

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1 November, 18 November, 1 December and 17 December) as main plots and four irrigation regimes (I_0: Control (Rainfed); I_1: 0.4 IW/CPE; I_2: 0.6 IW/CPE and I_3: 0.8 IW/CPE / I_1: 0.4 IW/CPE; I_2: 0.6 IW/CPE; I_3: 0.8 IW/CPE and I_4: 1.0 IW/CPE) as sub-plots replicated thrice in *kharif* 2016 and in *rabi* 2016-17. During the crop growth period, a rainfall of 834.9 mm was received in 45 rainy days in *kharif* 2016 and 11.8 mm in 2 rainy days in *rabi* 2016-17, respectively. A uniform dose of 60 kg ha^{-1} P_2O_5 as single super phosphate, potassium @ 60 kg ha^{-1} as muriate of potash and $ZnSO_4$ @ 50 kg ha^{-1} was applied to all the treatments. The entire P_2O_5, $ZnSO_4$ and half of K_2O were applied at sowing. Nitrogen was applied as per the treatments in the form of urea (46% N) in three equal splits (1/3rd each at basal, at knee-high and tasseling). Similarly, the remaining potassium was applied along with urea during second top dressing at tasseling. Gross plot size and net plot size were 6.0 x 4.2 m and 3.6 x 3.4 m respectively during both seasons. Five cobs were randomly selected from net plot and in each cob, the number of rows was counted and finally the mean number of rows cob^{-1} was achieved. From the randomly selected five cobs, the number of grains row^{-1} was counted and finally the mean number of grain row^{-1} was determined. Five samples each of 100 grains were collected randomly from the net plot produce treatment wise and weighed, averaged and expressed in grams. The kernels from the air-dried cobs from each net plot were separated, cleaned and dried to obtain at least 13 per cent moisture. Weight of grains of each plot was recorded separately and expressed as grain yield in kg ha^{-1}.

Effective rainfall (mm) during crop growing season was calculated using soil water balance method to impose the irrigation treatments as per the IW/CPE ratio (Dastane, 1974). Based on soil water holding capacity, a common depth of 50 mm of water was given to the respective treatments. Irrigation water applied under different IW/CPE ratios was measured with water meter and after delivering the 50 mm of water to the plot withheld the irrigation. Amount of irrigation water (mm) given was calculated based on the number of irrigations given during entire growing season. Water Use efficiency (WUE) is the amount of economic yield produced per unit quantity of water used. WUE was calculated by using the following formula and expressed as kg ha^{-1} mm^{-1} (French and Schultz, 1984).

$$WUE = \frac{\text{Economic yield or Seed yield (kg ha}^{-1})}{\text{Total water applied (mm)}}$$

The expenditure incurred from sowing to harvest was worked out for each treatment and expressed in ₹ ha^{-1} as cost of cultivation. Gross monetary returns (₹ ha^{-1}) were calculated by multiplying the grain and stover yield with their respective prevailing market price (Perin *et al.,* 1979). Net returns (₹ ha^{-1}) were calculated by subtracting the cost of cultivation from gross returns for each treatment. Benefit cost ratio was calculated by dividing gross returns with cost of cultivation for each treatment. The data were analyzed statistically applying analysis of variance technique for split plot design. The significance was tested by 'F' test (Snedecor and Cochron, 1967).

RESULTS AND DISCUSSION

Number of rows cob^{-1} and Number of grains row^{-1}

During *kharif* 2016, 4 July (D_2) sown crop recorded the highest number of rows cob^{-1} (15.3) and number of grains row^{-1} (24.4), which were found superior to 19 July (D_1), 18 June (D_1) and 10 August (D_4) sown crop (Table 1). However, 19 July (D_3) sown crop was comparable to that of 18 June (D_1) sown crop and the lowest number of rows cob^{-1} (13.6) and number of grains row^{-1} (19.0) was recorded with late sown 10 August (D_4). During rabi, 1 November (D_1) sown crop showed higher number of rows cob^{-1} (13.2) and number of grains row^{-1} (22.5), which was significantly higher than 17 November (D_2), 1 December (D_3) and 18 December (D_4) sown crops. Due to delay in sowing, upto 10 August (D_4) and 18 December (D_4), there was a reduction in number of grains row^{-1} by 22% and 8% over 4 July (D_2) and 1 November (D_1) sown crops during *kharif* 2016 and *rabi* 2016-17 respectively.

Similarly, the highest number of rows cob^{-1} (14.5) and number of grains row^{-1} (25.5) was observed in I_3 (0.8 IW/CPE) which was comparable to I_2 (0.6 IW/CPE) and I_1 (0.4 IW/CPE) but significantly superior to I_0 (rainfed) during *kharif* season (Table 1). During *rabi* 2016-17, the highest number of rows cob^{-1} (14.8) and number of grains row^{-1} (25.2) was recorded with I_4 (1.0 IW/CPE) which was significantly superior to I_3 (0.8 IW/CPE), I_2 (0.6 IW/CPE) and I_1 (0.4 IW/CPE). The lowest number of rows cob^{-1} (13.8, 10.3) and number of grains row^{-1} (18.6, 17.2) registered in I_0 (rainfed) in *Kharif* 2016 and I_1 (0.4 IW/CPE) in *rabi* 2016-17 respectively. Scheduling of irrigation at 0.8 IW/CPE and 1.0 IW/CPE increased the number of grains row^{-1} by 27% and 32% over control (I_0) during *Kharif* 2016 and 0.4 IW/CPE (I_1) during *rabi* 2016-17 respectively.

Table 1. Yield attributes and grain yield of maize as influenced by dates of sowing and irrigation schedules

Date of sowing (D)		No. of rows cob^{-1}		No. of grains row^{-1}		Test weight (g)		Grain yield (kg ha^{-1})	
Kharif	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***
18-Jun (D_1)	01-Nov (D_1)	14.0	13.2	22.5	22.5	27.3	26.8	5600	5396
04-Jul (D_2)	17-Nov(D_2)	15.3	12.8	24.4	21.6	30.2	25.0	6963	4777
19-Jul (D_3)	01-Dec (D_3)	14.2	12.8	23.6	21.3	28.0	25.0	5961	4775
10-Aug (D_4)	18-Dec (D_4)	13.6	12.6	19.0	20.8	21.9	23.8	3011	4047
S.Em±		0.1	0.1	0.4	0.3	0.6	0.4	105	100
CD (P=0.05)		0.3	0.2	1.3	0.9	2.2	1.3	364	345
Irrigation schedules (I)									
Kharif	***Rabi***								
Control (Rainfed) (I_0)	0.4 IW/CPE (I_1)	13.8	10.3	18.6	17.2	24.4	20.9	4108	2464
0.4 IW/CPE (I_1)	0.6 IW/CPE (I_2)	14.2	12.4	22.0	21.3	26.5	24.7	5333	3837
0.6 IW/CPE (I_2)	0.8 IW/CPE (I_3)	14.5	13.9	23.5	22.5	28.1	26.1	5725	5588
0.8 IW/CPE (I_3)	1.0 IW/CPE (I_4)	14.5	14.8	25.5	25.2	28.5	28.9	6369	7105
S. Em± 0.2		0.2	0.6	0.3	0.6	0.3	186	167	
CD (P=0.05)		0.4	0.5	1.8	0.8	1.7	1.0	544	487
Interaction (D X I)									
S. Em±		0.3	0.4	1.2	0.5	1.2	0.6	373	334
CD (P=0.05)[a]		NS	NS	NS	NS	NS	NS	NS	NS
S. Em±		0.3	0.3	1.1	0.5	1.2	0.7	339	306
CD (P=0.05)[b]		NS	NS	NS	NS	NS	NS	NS	NS

a = Difference of two Irrigations at same levels of dates of sowing
b = Difference of two dates of sowing at same or different levels of irrigations
NS= Not significant at P=0.05

The reduction in grain rows cob^{-1} could be due to progressive increase in moisture deficit specifically during vegetative stage of the crop growth. This led to pollen sterility and reduced receptability of silk for fertilization in later stages. A hybrid's genetics is instrumental in determining the potential number of rows cob^{-1} and environmental factors have a lesser influence. Yet, the amount of water received will affect the number of grain row^{-1}. The water deficits imposed at later crop growth period have been shown to cause delay in emergence of silk and inhibition of pollination resulting in considerable reduction in grain rows cob^{-1} and number of grains cob^{-1} (Harder *et al.,* 1982).

Test weight (100 grain weight)

During *kharif* 2016, the highest test weight (30.2 g) was noticed when the crop was sown on 4 July (D_2), which was superior to 19 July (D_3), 18 June (D_1) and 10 August (D_4) sown crop (Table 1). However, 19 July (D_3) sown crop was comparable to that of 18 June (D_1) and the lowest test weight (21.9 g) was observed in 10 August (D_4) sown crop. During *rabi* 2016-17, the highest test weight (26.8 g) was noticed in 1 November (D_1) sown crop, which was superior to 17 November (D_2), 1 December (D_3) and 18 December (D_4) sown crop. However, the lowest test weight (23.8 g) was recorded with 18 December (D_4) sown crop. The early sown crop associated with higher DM accumulation has contributed more carbohydrates during grain filling stage thus resulted in higher test weight of grains which confirms the find-ing of Law-Ogbomo and Remison (2009).

Among irrigation scheduling during *kharif* 2016, the highest test weight (28.5 g) was obtained with I_3 (0.8 IW/CPE) which was however on par with I_2 (0.6 IW/CPE) and significantly higher over I_1 (0.4 IW/CPE) and I_0 (rainfed). However, I_2 (0.6 IW/CPE) was comparable with I_1 (0.4 IW/CPE). The lowest test weight was obtained (24.4 g) with rainfed (I_0) treatment. However, significantly higher test weight (28.9 g) was obtained with I_4 (1.0 IW/CPE) over I_3 (0.8 IW/CPE), I_2 (0.6 IW/CPE) and I_1 (0.4 IW/CPE) during *rabi* season. The lowest test weight was obtained (20.9 g) with irrigation scheduling at 0.4 IW/CPE (I_1). The increase in test weight with irrigation scheduling at 0.8 IW/CPE (I_3) over control (I_0) and 1.0 IW/CPE (I_4) over 0.4 IW/CPE (I_1) was 14% and 28%, respectively in *kharif* and *rabi* respectively.

Alemi (1981) reported that the water stress in maize reduced test weight by 8% as compared to non-stress condition. Adequate soil moisture promoted meristematic and physiological activities such as plant leaf spread, root development, plant DM production *etc.*, leading to an efficient absorption and translocation of water and nutrients, interception of solar radiation and assimilation of carbon dioxide. These activities promote higher photosynthetic activities leading to the production of enough assimilate for subsequent translocation to various sinks and hence the production of higher yield components and yield of maize (Jaliya *et al.,* 2008).

Grain yield

During *kharif* 2016, higher grain yield of maize was obtained with the crop sown on (6963 kg ha^{-1}) 4 July (D_2), was significantly higher than 19 July (D_3), 18 June (D_1) and 10 August (D_4) sown crops. The lowest grain yield (3011 kg ha^{-1}) was recorded when delayed sowing was done on 10 August (D_4) (Table 1). During *rabi* 2016-17, 1 November (D_1) sown crop recorded the highest (5396 kg ha^{-1}) grain yield, which was significantly greater than that of 17 November (D_2), 1 December (D_3) and 18 December (D_4) sowing dates. However, 17 November (D_2) sown crop, in turn was comparable with that of 1 December (D_3) sown crop. The lowest grain yield was observed in 18 December (D_4) sown crop (4047 kg ha^{-1}). Delayed sowing on 10 August (D_4) and 18 December (D_4) respectively in *kharif* and *rabi* seasons reduced the grain yield by 57% and 25% over 4 July (D_2) and 1 November (D_1).

The yield enhancement with optimum sowing date was probably due to improved physiological conditions during the silking period for optimum kernel set (Barbieri *et al.,* 2000 and Rani *et al.,* 2012). Late sowing of maize manifested significant reduction in grain yield. Low growth rate in the late sown crop could be mainly due to unfavorable environmental effects encountered during the reproductive phase and might be due to the low net assimilation rate.

The grain yield of maize during *kharif* season was highest (6369 kg ha^{-1}) in 0.8 IW/CPE (I_3) treatment and was significantly superior to I_2 (0.6 IW/CPE), I_1 (0.4 IW/CPE) and I_0 (rainfed) (Table 2). However, I_2 (0.6 IW/CPE) was comparable to I_1 (0.4 IW/CPE) and the lowest grain yield (4108 kg ha^{-1}) was with

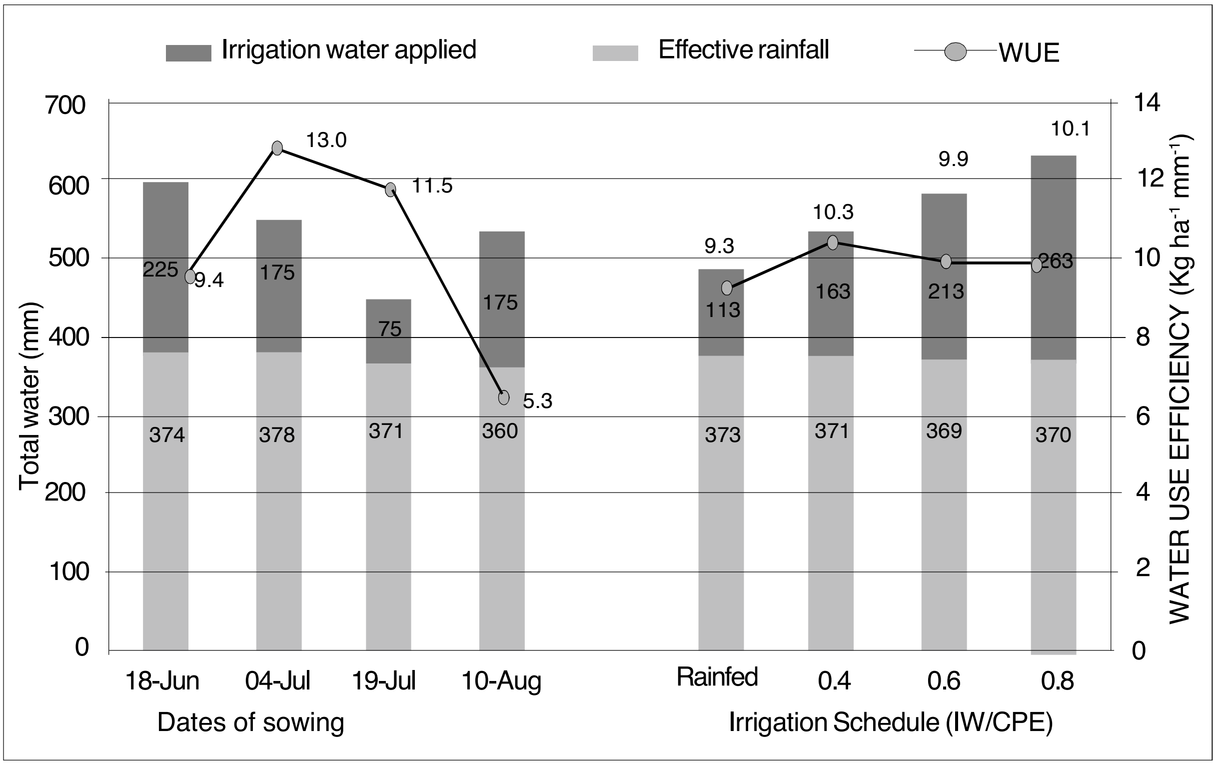

Figure 1. Water requirement and water use efficiency as influenced by dates of sowing and irrigation schedules in maize during *Kharif* 2016

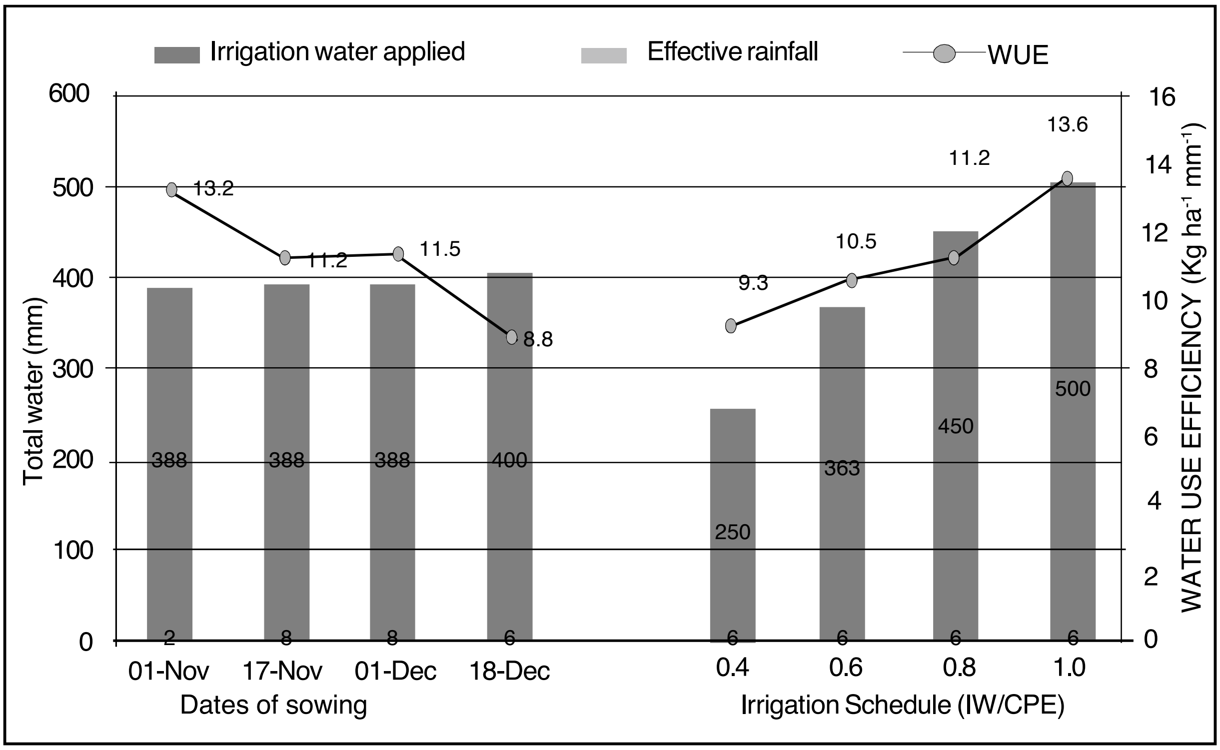

Figure 2. Water requirement and water use efficiency as influenced by dates of sowing and irrigation schedules in maize during *rabi* 2016-17

control (I_0). During *rabi* 2016-17 significantly higher grain yield (7105 kg ha^{-1}) was obtained with I_4 (1.0 IW/CPE) over I_3 (0.8 IW/CPE), I_2 (0.6 IW/CPE) and I_1 (0.4 IW/CPE). The lowest grain yield was obtained (2464 kg ha^{-1}) with irrigation scheduling of 0.4 IW/CPE (I_1). The increase in grain yield with irrigation scheduling of 0.8 IW/CPE (I_3) over control (I_0) and 1.0 IW/CPE (I_4) over 0.4 IW/CPE (I_1) was 36% and 65%, respectively in *Kharif* 2016 and *rabi* 2016-17 respectively.

The results of the study showed that the yield and yield components were limited by soil moisture content and low temperature stress in the delayed sowing date. The above trends in grain yield levels registered under 0.8 IW/CPE (I_3) and I_4 (1.0 IW/CPE) in comparison to other treatments could be traced to the favourable soil water balance (effective rainfall + applied water) as was observed by variation in soil moisture during the crop growing season during *kharif* and *rabi* respectively. This reduction in water use is accompanied by decrease in plant water content affecting the crop growth and development of the plants resulting in reduced crop yields (Kumar *et al.,* 2013).

Total water requirement and Water Use Efficiency

It includes supplementing water through irrigation for proper germination and establishment of the crop, water applied as per the treatments imposed and effective rainfall. The water applied in each treatment and water use efficiency are depicted in Figure 1 and 2. In *kharif*, crop sown on 18 June (D_1), 04 July (D_2), 19 July (D_3) and 10 August (D_4) received 599, 553, 546, 535 mm of water respectively. The treatment where irrigation was scheduled at 0.8 IW/CPE (I_3) received 633 mm of water and was followed by 0.6 IW/CPE (I_2) with 582 mm of water, 0.4 IW/CPE (I_1) with 533 mm of water and by rainfed (I_0) maize which received 485 mm of water. During *rabi* 2016-17, crop sown on 01 November (D_1), 17 November (D_2), 01 December (D_3) and 18 December (D_4) received 390, 395, 395, 406 mm of water respectively. Whereas, irrigation scheduled at 1.0 IW/CPE (I_4) received 506 mm of water and was followed by 0.8 IW/CPE (I_3) with 456 mm of water, 0.6 IW/CPE (I_1) with 368 mm of water and by 0.4 IW/CPE (I_1) maize which received 256 mm of water.

Higher WUE (13.0 kg ha-mm^{-1}) was recorded with 04 July and was followed by 19 July (11.9 kg ha-mm^{-1}), 18 June (9.4 kg ha-mm^{-1}) and 10 August (5.3 kg ha-mm^{-1}) during *kharif* 2016. Whereas, during *rabi* the higher water use efficiency (13.2 kg ha-mm^{-1}) was observed with 01 November followed by 01 December (11.5 kg ha-mm^{-1}), 17 November (11.2 kg ha-mm^{-1}) and 18 December (8.8 kg ha-mm^{-1}) sown crop. Maize water productivity depends on the amount of water applied, where with increase in irrigation water reduces the water productivity and such similar results were also reported by Hassanli *et al.* (2009). The lower WUE associated with higher amount of irrigation water could be due to a greater loss of water by evapotranspiration (ET) than the corresponding increase in seed yield (Kamkar *et al.,* 2011).

Among irrigation schedules, the higher WUE of 10.3 kg ha-mm^{-1} was registered with irrigation scheduled at 0.4 IW/CPE (I_1) and was followed by 0.8 IW/CPE (I_3), 0.6 IW/CPE (I_2) and rainfed (I_0) maize with water use efficiency of 10.1, 9.9 and 9.3 kg ha-mm^{-1} of water, respectively during *kharif* 2016. Whereas in *rabi* 2016-17, higher WUE of 13.6 kg ha-mm^{-1} of water was obtained with 1.0 IW/CPE (I_4) maize and was followed by irrigation scheduled at 0.8 IW/CPE (I_3) and 0.6 IW/CPE (I_2) with water use efficiency of 11.2 and 10.5 kg ha-mm^{-1} of water. However, the reduced water use efficiency of 9.3 kg ha-mm^{-1} of water was recorded with 0.4 IW/CPE (I_1).

Maximum WUE (13.6 kg ha-mm^{-1}) was observed in the treatment which received irrigations at knee-high, tasseling, silking, milk and dough stages and 1.0 IW/CPE (Ramulu *et al.,* 2006). WUE was significantly decreased with reduction in the amount of irrigation water, possibly due to the decrease in seed yield with increased drought stress (Feyzbakhsh *et al.,* 2015). However, severe drought stress may reduce WUE due to yield reduction and less dry matter accumulation. Stunted growth due to drought stress results in lower LAI, which in turn reduces WUE. Forced stomatal closing due to drought stress interferes with CO_2 uptake and O_2 release from the intercellular spaces of leaves resulting in a decrease in photosynthetic rate. Reduced photosynthetic rate causes a reduction in WUE as it affects the yield output of crops. Similarly, drought and high temperature stresses during *rabi* can lead to the harmful process of photorespiration, and thus carbon assimilation could be significantly reduced with a resulting reduction in WUE. Insufficient soil moisture availability makes the soil nutrients, especially N, immobile, and thus NUE is reduced (Ullaha *et al.,* 2019).

Table 2. Gross returns, net returns and B:C ratio of maize as influenced by dates of sowing and irrigation schedules

Date of sowing (D)		Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		B:C ratio	
Kharif	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***
18-Jun (D_1)	01-Nov (D_1)	84278	82866	50007	47209	1.46	1.32
04-Jul (D_2)	17-Nov (D_2)	104331	73303	70260	37746	2.06	1.05
19-Jul (D_3)	01-Dec (D_3)	89922	73382	55851	37825	1.64	1.05
10-Aug (D_4)	18-Dec (D_4)	46452	62506	12381	26649	0.36	0.74
	S.Em±	1466	1337	1466	1337		
	CD (P=0.05)	5072	4627	5072	4627		
Irrigation schedules (I)							
Kharif	***Rabi***						
Control (Rainfed) (I_0)	0.4 IW/CPE (I_1)	62284	38838	28463	4081	0.84	0.12
0.4 IW/CPE (I_1)	0.6 IW/CPE (I_2)	80501	59317	46480	23610	1.37	0.66
0.6 IW/CPE (I_2)	0.8 IW/CPE (I_3)	86300	85588	52079	49681	1.52	1.39
0.8 IW/CPE (I_3)	1.0 IW/CPE (I_4)	95897	108313	61476	72056	1.79	1.99
	S. Em±	2675	2429	2675	2429		
	CD (P=0.05)	7808	7091	7808	7091		
Interaction (D X I)							
S. Em±		5350	4859	5350	4859		
CD (P=0.05)[a]		NS	NS	NS	NS		
S. Em±		4860	4415	4860	4415		
CD (P=0.05)[b]		NS	NS	NS	NS		

a= Difference of two Irrigations at same levels of dates of sowing
b= Difference of two dates of sowing at same levels of irrigations
NS= Not significant at P=0.05

Economics

Gross returns, net returns and B:C ratio decreased consistently with subsequent delay in sowing in both the seasons of the study as that of grain yield (Table 2). During *kharif* 2016, the highest net returns (₹ 70260 ha^{-1}) and B:C ratio (2.06) was recorded with 4 July (D_2) sown crop, which was superior to 19 July (D_3), 18 June (D_1) and 10 August (D_4) sown crop. However, 19 July (D_3) was comparable to that of 18 June (D_1) sown crop and the lowest net returns (₹ 12381 ha^{-1}) and B:C ratio (0.36) was recorded with 10 August (D_4) sown crop. Among irrigation schedules, the highest gross returns (₹ 95897 ha^{-1}), net returns (₹ 61476 ha^{-1}) and B:C ratio (1.79) were recorded with I_3 (0.8 IW/CPE) which was significantly superior to I_2 (0.6 IW/CPE), I_1 (0.4 IW/CPE) and I_0 (rainfed). However, I_2 (0.6 IW/CPE) was comparable to that of I_1 (0.4 IW/CPE) and rainfed control (I_0) which registered the lowest gross returns (₹ 62284 ha^{-1}), net returns (₹ 28463 ha^{-1}) and B: C ratio (0.84).

During *rabi* season maize sown on 1 November (D_1) gave significantly higher net returns (₹ 47209 ha^{-1}) and B:C ratio (1.32) over 17 November (D_2), 1 December (D_3) and 18 December (D_3) sown crop. However, 17 November (D_2) was comparable to 01 December (D_3) sown crop, while the least net returns (₹ 26649 ha^{-1}) and B:C ratio (0.74) with 18 December (D_4) sown crop. Out of irrigation schedules, the highest gross returns (₹ 108313 ha^{-1}), net returns (₹ 72056 ha^{-1}) and B:C ratio (1.99) were recorded with I_4 (1.0 IW/CPE) which was significantly superior to I_3 (0.8 IW/CPE), I_2 (0.6 IW/CPE) and I_1 (0.4 IW/CPE), while lowest gross returns (₹ 38838 ha^{-1}), net returns (₹ 4081 ha^{-1}) and B:C ratio (0.12) was registered with I_1 (0.4 IW/CPE). With increase in number of irrigations from nil to three and three to eight increased the B:C ratio from 0.84 to 1.79 and from 0.12 to 1.99 during *kharif* and *rabi* respectively.

The results of current investigation clearly indicated that, significantly higher number of rows cob^{-1}, number of grains row^{-1}, test weight, grain yield, WUE, net returns and B:C were observed on 4 July (D_2) and 1 November (D_1) sown crops in *kharif* 2016 and *rabi* 2016-17 respectively compared to other dates of sowing. Similarly IW/CPE ratio of 0.8 and 1.0 were found optimum for scheduling irrigation to maize respectively during kharif and rabi seasons to obtain better yields and higher returns.

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Research Article
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MORPHOLOGICAL AND MOLECULAR CHARACTERIZATION OF *XANTHOMONAS ORYZAE* PV. *ORYZAE* (ISHIYAMA), THE LEAF BLIGHT PATHOGEN OF RICE (*ORYZA SATIVA* L)

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ABSTRACT

Bacterial blight disease of rice is a serious threat to rice cultivation of India. *Xanthomonas oryzae* pv. *oryzae*, (*Xoo*) the causal organism of bacterial blight disease of rice was isolated from diseased leaf samples and pure cultured on MW medium. The culture was tested for its pathogenicity on 65 days old seedling of a susceptible rice cultivar Taichung Native-1. With the help of SES scoring, the cultivar was found to be highly susceptible to the isolate after 30 days of pathogen inoculation. The culture was microscopically and molecularly identified. Microscopic visualisation of the bacteria through compound microscope at 100X magnification and scanning electron microscope at 9.00K magnification confirmed that bacterial cells appeared in the form of rod shaped measuring each cell size of 1.2 x 0.52 μm. The culture was confirmed as *Xoo* through molecular identification by using 16S and 23S rDNA gene specific primers. The conserved region of the isolate was amplified and the size was found to be of 470bp in agarose gel electrophoresis The nucleotide sequence obtained was BLAST and was submitted to NCBI. The accession number obtained for *Xoo* was MZ158566. Motif analysis of closest species with native *Xoo* was performed and four conserved sequences were obtained among the tested strains.

Rice being the most important crop across the world has occupied a very important role in the agriculture and food security of India (Misukami and Wakimoto, 1969). Change in climate, cultivation practices and extensive use of nitrogenous fertilizers have given easy and open pathway for various biotic and abiotic stresses in rice (Najeeya *et al.* 2007). Among the diseases, bacterial blight is the most devastating disease of rice which causes annually 50-80% yield loss (Yugander *et al.* 2018). It is commonly found in irrigated, rainfed and deep water mostly temperate and tropical rice growing areas, including all Asian countries, West Africa, Australia and South America. In India, it is the major problem in *Kharif* season in different rice growing regions of Punjab, Haryana, Uttaranchal, Bihar, West Bengal, Tripura, Assam, Tamil Nadu, Karnataka, coastal areas of Andhra Pradesh, Eastern Uttar Pradesh and Andaman and Nicobar Islands, Kerala, parts of Maharashtra, Chhattisgarh, Gujarat and Himachal Pradesh (Mew, 1982).

The causal agent *Xanthomonas oryzae* pv. *oryzae* (*Xoo*) is a gram negative, rod shaped, polar flagellate yellow bacterium which enters the plant through hydathodes, stomata or wounds (Yasmin *et al.* 2016). The yellow colour is due to the non-diffusible pigment xanthomonadin (brominated aryl-polyene) pigment which plays a major role in pathogenesis, symptomatology and also provides protection against photodamage of the bacterium (Rajagopal *et al.* 1997: Goel *et al.* 2002). The ideal temperature for pathogen development is about 25-34^{o}C, with a relative humidity of more than 70 per cent (Laha *et al.* 2009). Typical symptoms of this disease start from tip rolling of the leaves followed by water- soaked wavy pale green lesions which later turns into yellowish strip on leaf blades as well as in the margins (Mew, 1987). Under severe disease conditions, complete drying up of leaves and wilting of plants occurs which is commonly known as Kresek phase and is often confused with physiological disorders or the rice tungro viral disease (Nayak *et al.* 2006).

For adoption of any change in the environment, sudden mutations which leads to pathotypic and genotypic diversities among isolates of *Xanthomonas oryzae* pv. o*ryzae* have been observed and reported (Adachi and Oku, 2000). Under these circumstances, molecular characterisation and genome identification of specific strains of *Xanthomonas oryzae* pv. *oryzae*, that particularly affect rice plants have become an

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important area of research for the scientists. Therefore, the present study was conducted to characterize *Xanthomonas oryzae* pv. o*ryzae* isolated from different rice growing areas of Telangana state.

MATERIAL AND METHODS

Collection of leaf blight affected samples

Experimental plots of ICAR- Indian Institute of Rice Research and farmers field (Neelayagudum village, Miryalaguda, Nalgonda) in Telangana state were selected for collection of bacterial blight affected leaf samples. From each rice field, samples were collected randomly from 10 hills (5 leaves/hill). The samples were preserved in brown paper bag and brought to the laboratory for isolation of bacterium.

Isolation of *Xanthomonas oryzae* pv. *Oryzae*

The rice leaves showing blight symptoms were cut into small pieces and sterilized with 70% ethanol for 15 sec followed by three successive washing with sterile distilled water. The surface sterilized leaves were bits, blot dried and placed in the petriplates containing Modified Wakimoto Medium (MWM). These plates were incubated in biological oxygen demand (BOD) incubator at 28±2°C. The smear (bacterial ooze out) around the leaf bits was observed and a loopful of this smear was streaked on a fresh solidified MW medium in petriplate. Regular observation of the plates was done and well isolated single colonies were picked and streaked with sterile loop on MWM for obtaining the pure culture.

Pathogenicity test

A susceptible rice cultivar Taichung Native 1 (TN1) was used to prove the pathogenicity of bacteria isolated from infected leaves. For this, the seeds were first soaked in 500 ppm of streptocycline for 6 hours to avoid the external seed contamination. The treated seeds were washed thoroughly and soaked in water for 18 hours. Disinfected seeds were sown in pots of 55x30 cm size. A loopful of culture was mixed in 10 ml of distilled water to obtain a suspension of 10^{7} CFU/ml. Sixty-five days old healthy seedlings were selected for inoculation of bacteria through leaf clipping method. The leaves of healthy seedlings were cut 5 cm from top using sterile scissor dipped in bacterial suspension. The inoculated plants were regularly observed for leaf blight symptoms. After the development of symptoms, the leaves with typical symptoms were again brought to the laboratory for reisolation of the bacterium and comparison with the original culture.

Microscopic examination

The first discriminative test for identifying the bacteria was done through gram staining which include addition of methylene blue as primary stain (2 min) to a heat fixed smear followed by Gram's iodine, the mordant (1min), decolorized with alcohol and counterstained with safranin (2 min). Then the slide was covered with coverslip and observed at 100X magnification in compound microscope. For more clear examination, scanning electron microscopy of the culture was conducted by following the procedure given by Bozzola and Russell (1999).

Genomic DNA isolation

The genomic DNA of *Xoo* was extracted and purified by using Machery-Nagel (MN) kit from fresh culture (log phase) grown on MW broth. For this 1ml of broth containing actively growing culture was poured into eppendorf tube and centrifuged for 10 minutes at 4°C using 10000 rpm speed to pellet the DNA. The supernatant was discarded and pellet was used for further study. A specific set of primers forward XORF (52 -GCATGACGTCATCGTCCTGT-32) and reverse XOR-R2 (52-CTCGGAGCTATATGCCGTGC-32) from the spacer region between the 16S and 23S rDNA were used for the identification of pure cultures of *Xoo*. The polymerase chain reaction (PCR) conditions included initial denaturation step of 95°C for 5 min followed by 30 cycles of 95°C for 1 min, 56°C for 1 min, 72°C for 1 min and final extension of 10 min at 72°C. After completion of PCR, quantity of DNA was analysed by using Nanodrop and gel electrophoresis method (3 μL of product on 1% agarose gel pre-stained with ethidium bromide and visualized under UV transilluminator).

Product purification and submission to NCBI

The PCR product was further analysed by agarose gel electrophoresis and sequenced by Eurofins Genomics India Private Ltd., Bengaluru, India. The aligned sequence obtained was arranged in FASTA format using Molecular Evolutionary Genetics Analysis (MEGA) software. FASTA sequence was uploaded in National Center for Biotechnology Information (NCBI) GenBank and was compared with other bacterial sequences using basic local alignment research tool (BLAST). After completion of submission process in NCBI genebank database, accession number was obtained.

Phylogenetic tree

The construction of phylogenetic tree was done based on data obtained from nucleotide BLAST in NCBI. Fifty sequences showing more than 97% similarity coefficient with the native *Xoo* strain were used for phylogeny analysis. This analysis was done using Geneious prime software and was cross checked with phylogenetic analysis pipeline by ETE3 and MEGA software.

Motif analysis

The nucleotide sequences (closest four from phylogenetic analysis) in NCBI database which showed 100% similarity coefficient with the native strain were selected for motif analysis to find out the conserved regions among them. This analysis was performed using MEME software.

RESULTS AND DISCUSSION

Isolation of *Xoo* from the infected leaf samples

After 48 hours of incubation, small (pinhead size), shiny, raised, mucoid, convex yellow colonies were identified as *Xoo*. Single colony was picked and streaked in plate and slants containing MWM. For long term storage, a loopful of culture was transferred to 20% sterile glycerol stock solution and stored at -80°C in refrigerator. The results were in line with Jones *et al.* 1989 who isolated different strains of *Xoo* from diseased plant samples which were characterised by the water-soaked lesions typically associated with margins of fully developed leaves. Similarly, Han *et al.* (2005) isolated *Xoo* from diseased samples and reported that the colonies were slightly convex and smooth with regular to irregularly diffused edges.

Pathogenicity test

Artificially inoculated rice plants showed typical symptoms starting from tip rolling of the leaves followed by water-soaked wavy pale green lesions which later turned into yellowish strip on leaf blades as well as in the margins. The leaves get completely dried and the standard evaluation system (SES) scored 9 after 30 days of inoculation (Fig. 1). Munner *et al.* (2007) compared two different inoculation methods *viz.,* pin pricking and leaf clipping of *Xoo* in rice plants raised under glasshouse conditions. Lesion length was recorded and scored at 14th and 21st day after inoculation. Results indicated that both the methods have equal efficiency in initiating BB symptoms in rice cultivars. Arshad *et al.* (2015) performed pathogenicity test for 30 *Xoo* isolates on susceptible rice cultivar, IR 24 with leaf clipping inoculation method under glasshouse conditions. Fourteen days after inoculation all the cultures were found pathogenic to rice plants and produced lesions on leaves which were scored through IRRI SES scale.

Fig 1: Isolation of *Xoo* from diseased leaf samples and proving pathogenicity

A B C D E

Note:

A : Isolation of *Xoo* from diseased sample.

B : Pure culture of *Xoo*.

C : Artificial inoculation of *Xoo*.

D : SES scale (IRRI).

E : Re-isolated pure culture of *Xoo.*

Microscopic examination

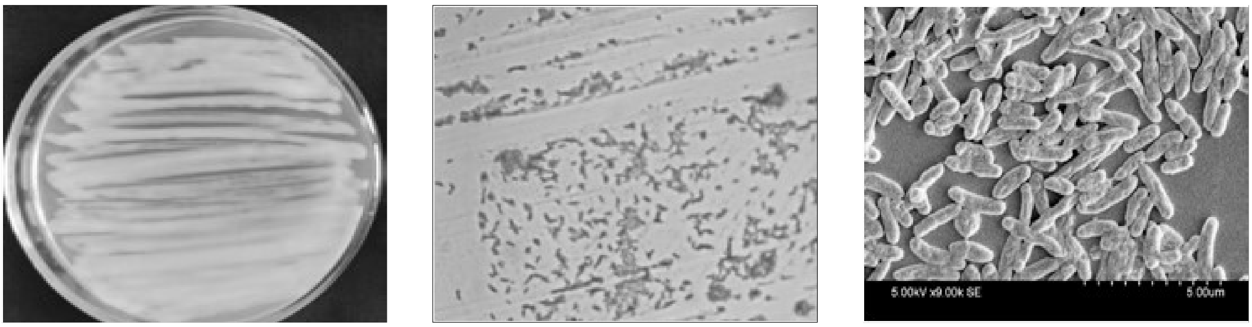
In compound microscope (100X), the bacterial cells of all the isolates appeared rod shaped and produced red colour when counter stained with safranin. This confirmed that the leaf blight causing bacterium is gram negative in nature. With the help of scanning electron microscopy, the size of single bacterium was analysed and bacterial cells appeared in the form of rod shaped measuring each cell size of 1.2 x 0.52 μm (Fig. 2). Abdallah *et al.* (2019) examined the *Xoo* structure and size with the help of scanning and transmission electron microscopy. Rafi *et al.* (2013) isolated 125 bacterial isolates from diseased samples and performed gram staining for differentiating bacteria into two broad groups *i.e.,* gram negative and gram positive. Hundred and two isolates out of 125 exhibited gram-negative reactions with pink or red colour when observed under compound microscope at 100x magnification as these isolates retained the colour of the counter stain *i.e.,* safranin.

neighbour joining approach in MEGA X software. Thirty one out of fifty species showed 100% similarity with native *Xoo* strain MZ158566 (Fig. 4). Similar results were obtained by Ramadass and Thiagarajan (2020) who isolated 10 *Xoo* isolates and tested the pathogenic efficiency. Of the 10 isolates, IL8 was found to be more virulent which was later molecularly characterised with the help of 16S rRNA and was confirmed as *Xanthomonas oryzae* pv. *oryzae*. They have analysed the phylogeny of existing *Xoo* database collected from NCBI and found that there were 2 strains having 100% similarity coefficient with IL8.

Motif analysis

A motif signifies repeated sequence patterns occurs among related species. MEME software discovers novel and ungapped motifs (recurring and fixed-length patterns) in sample sequences (sample output from sequences). MEME splits variable-length patterns into two or more separate motifs. With the

Fig 2: Morphological characteristics of *Xoo*



A
Culture morphology on MWM

B
Cell morphology under compound microscopic (100X)

C
Cell morphology under SEM

Nucleotide sequence analysis and construction of phylogenetic tree

With the help of specific primers, the conserved region of the isolate was amplified and the size was found to be of 470bp in agarose gel electrophoresis (Fig. 3). The nucleotide sequence obtained was BLAST and the results were compared with the database of NCBI. The isolate was identified as *Xanthomonas oryzae* pv. *oryzae* and the sequence was submitted to NCBI (Accession number: MZ158566) (Table 1). Fifty known sequences which showed more than 97% similarity with sequences of *Xanthomonas oryzae* pv. *oryzae* submitted to NCBI database were collected and the phylogenetic tree was constructed using

Fig. 3: Gel electrophoresis of isolated *Xoo* strain

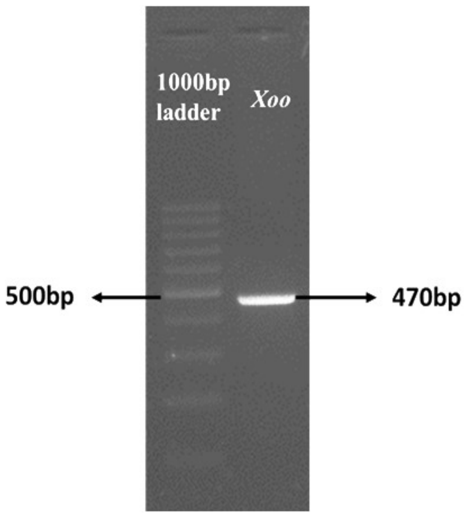
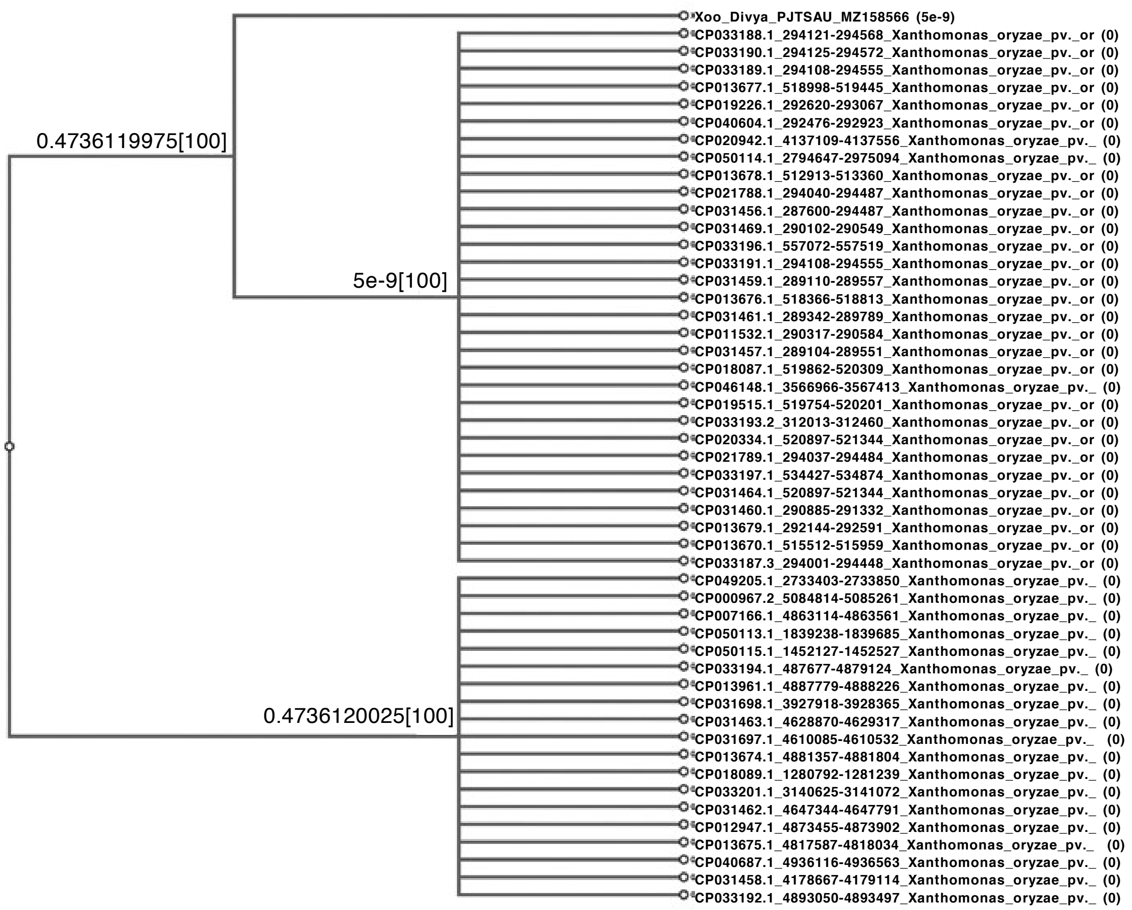


Table 1. Details of culture submitted to NCBI

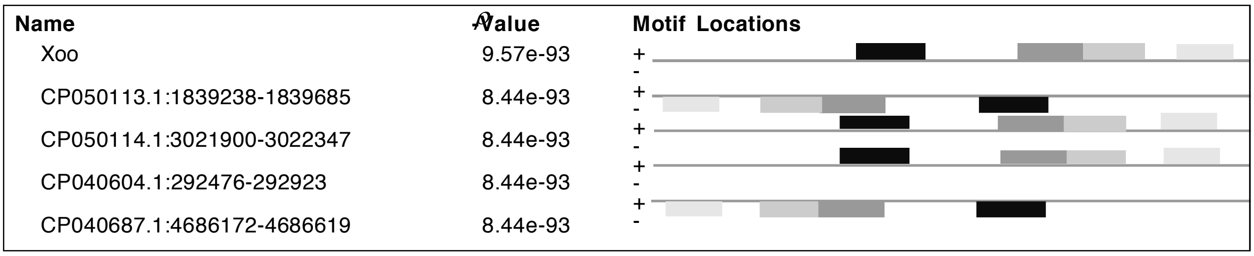
Organism	Classification	Definition	NCBI Accession number	Submitted sequence
Xanthomonas oryzae pv. *oryzae*	Bacteria; Proteobacteria; Gammaproteobacteria; Xanthomonadales; Xanthomonadaceae; Xanthomonas	*Xanthomonas oryzae* pv. *oryzae* strain 1D 16S-23S ribosomal RNA intergenic spacer, partial sequence	MZ158566	1 gcatgaaggg tacgtcctgt cgggcgtcct cacaaattac ctgcattcag agattcatac 61 cggcacaggt tcggtatgcg aagtcccttt tggggcctta gctcagctgg gagagcacct 121 gctttgcaag cagggggtcg tcggttcgat cccgacaggc tccaccatat tgagtgaaaa 181 gacttcgggt ctgtagctca ggtggttaga gcgcacccct gataagggtg aggtcggtag 241 ttcgagtcta cccagaccca ccactctgaa tgtagtgcac acttaagaat ttatatggat 301 cagcgttgag gctgagacat gttcttttat aacttgtgac gtagcgagcg tttgagatat 361 ctatctaaac gtgtcgttga ggctaaggcg gggacttcga gtccctaaat aattgagtcg 421 tatgttcgcg ttggtggctt tgtactccac acagcacggc a

Fig 4: Phylogenetic analysis of 50 isolates of *Xanthomonas oryzae* pv. *oryzae*



help of TOMTOM programme, DNA sequences of all *Xoo* strains under the study were subjected to similar motifs analysis. Analysis showed 4 motifs which were found to be conserved in the DNA sequences (Fig. 5 and Table 2). Conserved sequences with the help of motif analysis helps us to find homology among different organisms and species during computational analysis (Shen *et al.* 2001). In relation to biological significance, the conserved sequences found between *Xoo* species are the coding sequences which may retain the structural and functional integrity of any particular protein present in the organism (Janda and Abbott, 2007).

Fig 5. Motif locations and consensus among the tested *Xoo* isolates



Motif Symbols	Motif Censensus
1.	TTAAGAATTTATATGGATCAGCGTTGAGGCTGAGACATGTTCTTTTATAA
2.	TAAATAATTGAGTCGTATGTTCGCGTTGGTGGCTTTGTACT
3.	TTGTGACGTAGCGAGCGTTTGAGATATCTATCTAAACGTGT
4.	TCCACCATATTGAGTGAAAAGACTTCGGGTCTGTAGCTCAGGTGGTTAGA

Table 2. Motif analysis of native *Xoo* isolate with closest other *Xoo* sequences

Isolates	Probability value	Start	E-value	Site count	Width
Xoo D: MZ158566	5.05e-31	283	1.1e-059	5	50
CP050113.1:1839238-1839685		130			
CP050114.1:3021900-3022347		270			
CP040604.1:292476-292923		270			
CP040687.1:4686172-4686619		130			
Xoo D: MZ158566	1.65e-25	406	6.5e-046	5	41
CP050113.1:1839238-1839685		16			
CP050114.1:3021900-3022347		393			
CP040604.1:292476-292923		393			
CP040687.1:4686172-4686619		16			
Xoo D: MZ158566	1.73e-25	334	1.2e-045	5	41
CP050113.1:1839238-1839685		88			
CP050114.1:3021900-3022347		321			
CP040604.1:292476-292923		321			
CP040687.1:4686172-4686619		88			
Xoo D: MZ158566	7.06e-31	161	1.0e-057	5	50
CP050113.1:1839238-1839685		225			
CP050114.1:3021900-3022347		148			
CP040604.1:292476-292923		148			
CP040687.1:4686172-4686619		225			

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Research Article
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PERFORMANCE OF SPINACH IN HEAVY METAL POLLUTED SOIL UNDER DIFFERENT DECONTAMINANTS

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ABSTRACT

An experiment was conducted at Student Farm, College of Agriculture, PJTSAU Rajendranagar, Hyderabad, during *kharif* 2016 to study the performance of spinach in heavy metal polluted soil under different decontaminants (different dosages of phosphorus, various levels of quick lime). The fresh and dry weight of spinach varied from 24.19 to 30.32, 2.56 to 3.42 t ha^{-1} respectively. Among the different decontaminants highest fresh weight (30.32 t ha^{-1}) and dry weight (3.42 t ha^{-1}) was obtained in T_5 (RDF+CaO @ 2 t ha^{-1}), which was significantly superior over all other treatments and on par with T_4 (RDF+CaO @ 1 t ha^{-1}) and per cent increase over RDF was 25.34, 33.59, respectively for fresh and dry weight of spinach. Decontamination treatments had reduced the mean Pb, Cd, Ni and Co contents of spinach to 17.86, 1.00, 2.86 and 3.94 mg kg^{-1} and increased mean uptake to 55.99, 3.14, 8.95 and 12.35 g ha^{-1} respectively for Pb, Cd, Ni and Co. The Pb, Cd, Ni and Co contents of soil after harvest of the spinach crop ranged from 19.58, 1.02, 2.58 and 2.58 mg kg^{-1} in the reference control and decreased to 15.58, 0.79, 2.34 and 2.34 with RDF+CaO @ 2 t ha^{-1} treatment. The reduction in Pb, Cd, Ni and Co concentration in post harvest soil was more due to Cao at different levels when compared to application of high phosphorus.

In India, due to rapid industrial development during the last few decades, disposal of industrial effluents has become serious problem, and application of industrial effluents to land became common means of disposal in the recent past (Solanki *et al.*, 2019). Besides being a useful source of plant nutrients, these effluents often contain high amounts of various organic and inorganic materials as well as heavy metals. Such industrial effluents when mixed with water and used for irrigation, becomes potential threat to soil physical, chemical and biological environment. The unscientific disposal of untreated or under treated effluents result in accumulation of heavy metals in soil and finally get entry into the human and animal food chain through the crops grown on it. Banning of crop cultivation in such toxic metal polluted soil, is the best option to reduce its contents or eliminate the entry of toxic metals into food chain. But real challenge to soil scientists lie in restoring these soils to normal levels within reasonable time and cost, as non-renewable sources like soils cannot be afforded to be left unused. The heavy metal contaminated soils can be remediated through two approaches *i.e.,* phytoremediation and chemical decontamination. Remediation methods available for reducing the harmful effects at heavy metal contaminated sites include chemical, physical and biological techniques. These can be grouped into two categories i.e. ex-situ and in-situ methods. The conventional ex-situ methods applied for remediating the polluted soils relies on excavation, detoxification and/or destruction of contaminant physically or chemically, as a result the contaminant undergo stabilisation, solidification, immobilisation, incineration or destruction (Padhan *et al.*, 2021). Identifying or evaluation of cost effective chemical amendments can be a key element for a new land management strategy for reclaiming heavy metal contaminated agricultural land. In this context the experiment was taken up to study the performance of decontaminants in spinach on a polluted soil.

MATERIAL AND METHODS

An experiment was conducted to know the effect of inorganic amendments in abetting the heavy metals pollution in a polluted soil at Student Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad. Soil of the experimental site was red sandy loam in texture, slightly acidic in reaction, normal in soluble salt content with available N (265 kg ha^{-1}), P_2O_5 (32 kg ha^{-1}) and K_2O (185 kg ha^{-1}) and DTPA

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extractable heavy metals Pb (20.24 ppm), Cd (1.06 ppm), Ni (2.61 ppm) and Co (2.59 ppm). The experiment was laid out in randomized block design with 5 treatments and 4 replications with spinach as a test crops. The treatments include T_1 RDF (only), $T_{2:}$ (T_1) + High phosphorus 150 %, $T_{3:}$ (T_1) + High phosphorus 200 %, $T_{4:}$ (T_1) + lime (CaO) 1 t ha^{-1}, $T_{5:}$ (T_1) + lime (CaO) 2 t ha^{-1}. The recommended dose of fertilizers for spinach is 80: 30: 30 kg N:P:K ha^{-1} and were applied in the form of urea, SSP and MOP respectively. The high phosphorus and quick lime were applied as per the treatments and mixed thoroughly in soil to ensure uniform distribution in the soil of respective plots. The crop was sown on 20.06.2016 and the irrigation and plant protection measures were taken up as and when required. The representative plant samples were collected in all the treatments at harvest of crop for analysis of heavy metals. The soil samples were taken up after harvest of the crop in all the treatments, were analyzed for all extractable heavy metals.

RESULTS AND DISCUSSION

Effect of applied decontamination treatments on yield (fresh and dry weight) of spinach

Fresh weight is the expression of growth and development of different morphological components and it is directly related to the yield. Fresh yield weight of spinach ranged from 24.19 to 30.32 with a mean of 27.84 t ha^{-1} (table 1). The decontamination treatments resulted in variation of fresh weight from 27.19 to 30.32 t ha^{-1} with mean fresh weight of 28.75 t ha^{-1}. Highest fresh yield was recorded with RDF + lime @ 2 t ha^{-1} (30.32 t ha^{-1}). Decontamination with high phosphorus and lime (1 and 2 t ha^{-1}) application had significantly increased the fresh weight of spinach over RDF treatment. Significant difference in yield was observed between the decontamination treatments *i.e.*, high phosphorus or lime but there is no significant variation in fresh yield weight within the high phosphorus applied either at 150 or 200% or lime applied at 1 or 2 t ha^{-1}. Similar trend was noticed with respect to dry weight of spinach. Dry weight ranged between 2.56 to 3.42 t ha^{-1} with a mean of 3.03 t ha^{-1}. Decontamination treatments had resulted in the mean yield of 3.15 t ha^{-1}. Increase in yields of spinach by the application of inorganic amendments may be attributed to suppression of heavy metals toxicity, improving soil physical condition and increase in mineral nutrition (Hamid *et al.*, 2019). This might be due to reduced detrimental effects of toxic metals in the soil for plant grown on polluted soil (Mathavan *et al.*, 2001). Ranjeet Kumar (2016) reported significantly increased yields of spinach due to application of organic and inorganic amendments in contaminated soil at New Delhi.

Table 1. Yield (t ha^{-1}) of spinach under various decontamination treatments

Treatments	Yield (t ha^{-1})	
	Fresh weight	Dry weight
T_1-100% RDF	24.19	2.56
T_2- T_1+High phosphorus 150 %	27.19	2.92
T_3-T_1+ High phosphorus 200 %	27.23	2.94
T_4-T_1+ lime (CaO) 1 t ha^{-1}	30.25	3.31
T_5-T_1+ lime (CaO) 2 t ha^{-1}	30.32	3.42
Mean of Decontaminants	28.75	3.15
Overall mean	27.84	3.03
S. Em$\pm$	0.99	0.12
CD (*P=0.05*)	2.99	0.36

Content and uptake of heavy metals by spinach

Contents of heavy metals (Table 2) in spinach ranged from 16.78 to 20.49, 0.94 to 1.11, 2.66 to 3.25 and 3.69 to 4.4 with a mean of 18.38, 1.02, 2.93 and 4.03 mg kg^{-1}, respectively for Pb, Cd, Ni and Co. The decontamination treatments had reduced the mean Pb, Cd, Ni and Co contents to 17.86, 1.00, 2.86 and 3.94 mg kg^{-1}, respectively resulting in 12.20, 10.14, 10.85 and 9.20 percent reduction compared to control (RDF) in the Pb, Cd, Ni and Co contents. High phosphorus application at 200% and calcium oxide treatments at 1 and 2 t ha^{-1} had significantly reduced the Pb, Cd Ni and Co contents when compared to the RDF treatment. Though, there was reduction in heavy metal content in high phosphorus applied at 150% but it was non-significant. Contents of Heavy metals with lime application either at 1 or 2 t ha^{-1} were significantly lower than that of high phosphorus applied treatments. The contents were on par with each other with the decontaminants i.e., high phosphorus or lime applied treatments. Total metal load in the spinach ranged between 24.07 and 29.25 with a mean of 26.37 mg kg^{-1}.

Table 2. Concentration (mg kg^{-1}) and uptake (g ha^{-1}) of heavy metals by spinach at harvest under different decontamination treatments

Treatments	Heavy metal concentration (mg kg^{-1})					Heavy metal uptake (g ha^{-1})				
	Pb	Cd	Ni	Co	Total metal load	Pb	Cd	Ni	Co	Total metal load
T_1-100% RDF	20.49	1.11	3.25	4.40	29.25	52.45	2.84	8.32	11.26	74.88
T_2-T_1+ High phosphorus 150 %	19.12	1.09	3.12	4.29	27.62	55.83	3.18	9.11	12.53	80.65
T_3-T_1+ High phosphorus 200 %	18.44	1.03	2.95	4.07	26.49	54.21	3.03	8.67	11.97	77.88
T_4-T_1+ lime (CaO) 1 t ha^{-1}	17.08	0.95	2.69	3.71	24.43	56.53	3.14	8.90	12.28	80.86
T_5-T_1+ lime (CaO) 2 t ha^{-1}	16.78	0.94	2.66	3.69	24.07	57.39	3.21	9.10	12.62	82.32
Mean of Decontaminants	17.86	1.00	2.86	3.94	25.65	55.99	3.14	8.95	12.35	80.43
Overall mean	18.38	1.02	2.93	4.03	26.37	55.28	3.08	8.82	12.13	79.32
S. Em$\pm$	0.61	0.02	0.09	0.11	0.89	1.65	0.12	0.27	0.15	2.48
CD (*P=0.05*)	1.83	0.07	0.28	0.30	2.69	NS	NS	NS	NS	NS

The percentage decrease in Pb, Cd, Ni and Co contents with the application of Cao @ 2 t ha^{-1} over RDF were to an extent of 18.10, 15.31, 18.15 and 16.13 per cent respectively. The reduction in heavy metal contents resulted in more increased yields with quick lime application when compared to reference control (RDF only). No significant influence of decontaminants on the heavy metal uptake by the spinach was observed. However heavy metal uptake viz., Pb, Cd, Ni and Co was high in decontamination treatments over Control (RDF). The highest metal (Pb, Cd, Ni and Co) uptake was noticed in the lime applied at 2 t ha^{-1}. The total heavy metal uptake by different treatments ranged from 74.88 to 82.32 g ha^{-1}.

Ranjeet Kumar (2016) found the significant reduction of Pb in plant parts of spinach in amended polluted soil when compared to non amended polluted soil at New Delhi. Pandit *et al.*, 2012 also reported that the application of amendment decreased the Cd concentration to an extent of 61 percent in spinach plant compared to unamended treatment in a contaminated soil. The immobilization of Cd and Pb through adsorption, complexation and precipitation phenomena, results in reduced phytotoxicity and accumulation in plants (Geebelen *et al.*, 2002; Seaman *et al.*, 2003). Park *et al.*, 2011 observed that Pb content in sunflower shoot reduced by 60-80% with amendments application in sewage polluted soils. Rehman *et al.* (2015) also found that gypsum application decreased the grain and straw Cd concentration in wheat and rice crops grown on contaminated soil at Faisalabad in Pakistan. Gypsum might be better amendments for *insitu* immobilization of Cd and some other heavy metals due to its low cost and frequent availability (Illere *et al.*, 2004). Ahmad *et al.* (2017) also found the reduction of Cd and Pb concentration in wheat with the addition of gypsum at Faisalabad. The percentage reduction of all the heavy metal content due to application of decontamination treatments over the control in spinach crop grown on polluted soil ranged from 6.68 to 18.10 per cent for Pb, 1.80 to 15.31 per cent for Cd, 4 to 18.15 per cent for Ni, and 2.5 to 16.13 per cent for Co. The maximum percentage reduction in heavy metals over the control was in T_5 treatment with CaO @ 2 t ha^{-1}. The reduction in heavy metals contents in spinach plant with the best treatment were in order as Ni >Pb>Co>Cd. According to Bolan *et al.* (2003) Ca^{+2} addition through lime inhibited the translocation of Cd, Pb and other heavy metals from root to shoot as these metals are accumulated primarily on cell walls of roots with only limited amounts translocated to shoot and grain. Stabilization of metals by these amendments through adsorption, complexation and reduction reaction (Brown *et al,*. 2003; O' Dell *et al.,* 2007). Chen *et al.* (2009) reported the significantly increased biomass of cauliflower with decrease in Pb content.

Table 3. Heavy metal status (mg kg^{-1}) in post harvest soil of spinach under different decontamination treatments

Treatments	Available heavy metal status (mg kg^{-1})			
	Pb	Cd	Ni	Co
T_1-100% RDF	19.88	1.02	2.58	2.58
T_2- T_1+High phosphorus 150 %	18.14	0.96	2.52	2.51
T_3-T_1+ High phosphorus 200 %	17.66	0.91	2.46	2.46
T_4-T_1+ lime (CaO) 1 t ha^{-1}	15.71	0.81	2.15	2.40
T_5-T_1+ lime (CaO) 2 t ha^{-1}	15.58	0.79	2.11	2.34
Mean of Decontaminants	16.77	0.87	2.31	2.43
Overall mean	17.39	0.90	2.36	2.46
S. Em$\pm$	0.66	0.03	0.09	0.07
CD(*P=0.05*)	1.98	0.09	0.28	0.23

Heavy metal status (mg kg^{-1}) in post harvest soil

The Pb, Cd, Ni and Co contents of soil after harvest of the spinach crop ranged from 19.58, 1.02, 2.58 and 2.58 mg kg^{-1} in the reference control to 15.58, 0.79, 2.34 and 2.34 in T_5 treatment (Table 3). The maximum reduction of heavy metals over the control in post harvest soils was recorded with CaO @ 2 t ha^{-1} (T_5), being 23.02, 25.47, 10.34 and 10.34 per cent for Pb, Cd, Ni and Co respectively. The reduction in Pb, Cd, Ni and Co in post harvest soils was more due to Cao at different levels when compared to application of high phosphorus being 11.77, 13.18, 4.87 and 4.87 per cent respectively. The reduction of available heavy metal contents in post harvest soils with the application of CaO might be due to the stabilization of metals by amendments.

CONCLUSION

It appears that inorganic amendment application might have decreased the available heavy metal contents in the soil and thereby providing more congenial atmosphere for spinach growth due to reduction in content there in plant. The quick lime do not contribute mineral nutrition to the plant directly, it can be concluded that this amendments helped in increasing fresh weight of spinach grown on polluted soils by reducing detrimental effects of toxic metal in soil for plant growth. Solubility and mobilizing of heavy metals of soil get reduced due to amendments application and hence their toxicity could be reduced. It was observed that available heavy metal contents in soil decreased in amendment treatment soil as compared to unamended soil. A reason for decrease in plant available heavy metals in soils may be due to the stabilization of metals by amendments.

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EVALUATION OF SUNFLOWER, *Helianthus annus* L. GERMPLASM ACCESSIONS AGAINST LEAFHOPPER, *Amrasca biguttula biguttula* Ishida UNDER FIELD CONDITIONS

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ABSTRACT

Field experiment was conducted during *Rabi* season 2016-17 and 2017-18 to screen 57 sunflower germplasm accessions along with commercial hybrid, Syngenta SB-275 and susceptible check, Morden to evaluate their reaction against sunflower leafhopper at ICAR-Indian Institute of Oilseeds Research (IIOR), Hyderabad, India. Based on mean scale index (MSI) the accessions were categorised as highly resistant, resistant, moderately resistant, susceptible and highly susceptible. During *Rabi* 2016-17, average leafhopper infestation ranged between 0.3 and 18.2 per three leaves per plant across the germplasm accessions. TSG- 349 recorded the lowest mean population of leafhoppers (0.3 per three leaves per plant) while highest number of leafhoppers were recorded on the susceptible check, Morden (18.2 per three leaves per plant), 22 accessions were found resistant, 25 were found moderately resistant and 10 were found susceptible. During *Rabi*, 2017-18, leafhopper infestation ranged between 2.2 and 32.4 per three leaves per plant. GMU-339 recorded the lowest mean population of leafhoppers (2.2 per three leaves per plant). Whereas, highest numbers of leafhoppers were recorded on the susceptible check, Morden (32.4 per three leaves per plant), 15 germplasm lines were categorized as resistant, 30 germplasm lines were identified as moderately resistant while to be 12 were susceptible. Considering both the years, consistently 15 accessions were identified as resistant and 23 accessions moderately resistant.

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in India popularly known as "Surajmukhi". It is an important source of high quality edible oil with wide adaptability to seasons and soils. Sunflower was introduced into India in 1969 and now occupies an area of 0.25 lakh hectares and production of 0.22 million tonnes and productivity of 886 kg per hectare (DAC & FW, 2020). In Telangana state, the crop was grown with an area of 0.10 lakh acres during *Rabi,* 2019 with production of 0.07 million tonnes and productivity of 687 kg per acre (DES, 2020). In India there are more than fifty insect species (seedling pests, sucking pests, soil insects, defoliators and inflorescence pests) feeding on sunflower at different phenological stages (Basappa and Prasad, 2005). In Telangana state, leafhopper *Amrasca biguttula biguttula* (Ishida) is the major pest in sunflower.

A. biguttula biguttula has a broad host range including cotton, okra, brinjal, eggplant, jute and sunflower. This pest is more serious in the tropics and subtropics because of the favorable environmental conditions for its growth and development round the year (Ramandeep, 2016). In sunflower, leafhopper population is predominantly observed during *Rabi* season. Both nymphs and adults of leafhopper suck the cell sap from the leaves and shows symptoms like stunted growth, burning of leaf margins, cupped and crinkled leaves. In severe case if infestation occurs, characteristic "hopper burn" is noticed. Leafhopper caused 25.2 and 41.0 per cent yield reduction in sunflower hybrid, KBSH-53 and variety, Morden, respectively (DOR, 2014) whereas in okra it caused 32.06 to 40.84 per cent damage (Singh and Brar, 1994) and 16.3 per cent reduction in seed yield of cotton (Ramalakshmi, 2012).

Reducing the cost of production is one of the important crop technologies in sunflower to increase the profitability of the crop. Host plant resistance in crop plants is an important component of Integrated Pest Management (IPM) and it is considered as non-monetary input. Use of resistant or less susceptible cultivars is one of the most significant methods of

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keeping insect populations below economic threshold levels. It is most helpful when carefully utilized with other components of pest management. Host plant resistance to leafhopper is being exploited in several research institutes and important sources of resistance have been identified. However, there are no durable resistant lines against leafhopper in sunflower. Keeping this in view few sunflower germplasm accessions were screened against leafhopper under natural field conditions to identify the sources of resistance that can be utilized in the breeding programmes.

MATERIAL AND METHODS

Screening and evaluation for leafhopper resistance was done in the field under unsprayed conditions taking advantage of the natural infestation.

A total of 57 germplasm accessions of sunflower collected from Germplasm Maintenance Unit (GMU), IIOR, Rajendranagar with different plant characters along with commercial hybrid, Syngenta SB-275 and susceptible check, Morden were screened during *Rabi*, 2016-17 and 2017-18 at IIOR farm, Rajendranagar. Each line was planted in single row of 3 m length at a spacing of 60 x 30 cm and 2 replications were maintained for each line. For every two rows of germplasm lines one row of Morden (susceptible check) was sown as infester row. Sowing was done on 08-12-2016 during *Rabi,* 2016-17 and on 17-1-2018 during *Rabi*, 2017-18. Crop was raised as per the IIOR recommended package of practices and no plant protection measures were taken up for leafhoppers, as the screening was done under natural infestation.

Observations on leafhopper population was recorded on five randomly selected plants per replication on 65 days old crop when peak leafhopper population was observed. The nymphs of leafhopper were counted on top, middle and lower leaves per plant.

Injury grade	Scoring of leafhopper injury
0	Free from leafhopper injury
1	Slight yellowish on the edges up to 30 per cent
2	Yellowing and curling up to 40 per cent leaves
3	Yellowing and curling up to 60 per cent leaves
4	Yellowing and curling up to 80 per cent leaves
5	Maximum, yellowing, cupping and curling up to 100 per cent

Leafhopper injury on five randomly selected plants was scored as per Ingale *et al.,* 2019 and grade was awarded as follows

On the basis of injury grade, Mean Scale Index (MSI) was determined as under;

$$MSI = \frac{(G0 \times P) + (G1 \times P) + (G2 \times P) + (G3 \times P) + (G4 \times P) + (G5 \times P)}{TP}$$

Where, G - Leafhopper Injury Grade (0 to 5)

P - The number of plants under the grade for each category

TP - Total number of plants taken for observation

MSI	Resistance category
0.0	Highly resistant
0.1-1.0	Resistant
1.1-2.5	Moderately resistant
2.6-3.5	Susceptible
3.6-5.0	Highly susceptible

Based on MSI, the accessions were grouped into five categories as given below (Ingale *et al.,* 2019).

The leafhopper susceptibility index (LHSI) for each accession was worked out by multiplying the average nymphal population per three leaves per plant with corresponding mean scale index (Mahal *et al.,* 1993).

RESULTS AND DISCUSSION

Rabi 2016-17

The average leafhopper infestation ranged between 0.3 and 18.2 per three leaves per plant across the germplasm accessions (Table 1). Among the germplasm lines, the accession TSG- 349 recorded the lowest mean population of leafhoppers (0.3 per three leaves per plant). Highest number of leafhoppers were recorded on the susceptible check Morden (18.2 per three leaves per plant) followed by PSECO-86 (15.6 per three leaves per plant) and PSMO-53-B-1 (15.0 per three leaves per plant). The population of leafhopper in the remaining 54 accessions ranged between 2.0 and 13.2 per three leaves per plant. Twenty two accessions were found resistant with an average MSI ranging from 0.6 and 1.0, while twenty five were found moderately resistant with an average MSI ranging from 1.1 and 2.2, ten germplasm lines were found susceptible with an average MSI ranging from 2.6 and 2.7. The commercial sunflower hybrid,

Table 1. Field screening of sunflower germplasm accessions against leafhopper, *Amrasca biguttula biguttula* (*Rabi*, 2016-17 and 2017-18)

S.no	Germplasm	2016 -17			2017-18		
		Average No. of leafhoppers/ three leaves/plant	MSI	LHSI	Average No. of leafhoppers/ three leaves/plant	MSI	LHSI
1	GMU-4	12.3	1.8	22.14	17.2	2.6	44.63
2	GMU-25	3.0	1.0	3.00	3.4	1.0	3.40
3	GMU-243	10.6	2.6	27.56	15.0	2.7	40.50
4	GMU-327	12.0	1.2	14.40	16.0	2.0	32.00
5	GMU-339	3.3	0.6	1.98	2.2	0.8	1.76
6	GMU-343	4.2	1.4	5.88	9.0	1.8	16.20
7	GMU-405	9.8	1.3	12.74	13.8	1.2	16.56
8	GMU-504	6.0	1.0	6.00	8.4	1.0	8.40
9	GMU-556	4.4	1.1	4.84	9.0	1.2	10.80
10	GMU-595	8.2	1.0	8.20	10.2	1.6	16.32
11	GMU-669	2.2	1.0	2.20	4.6	1.0	4.60
12	GMU-696	2.9	1.0	2.90	5.2	1.0	5.20
13	GMU-713	8.4	1.2	10.08	11.2	1.6	17.92
14	GMU-776	7.4	1.0	7.40	5.4	1.0	5.40
15	GMU-922	9.6	1.0	9.60	13.6	1.8	24.48
16	GMU-1029	4.2	1.0	4.20	10.4	1.2	12.48
17	GP-6-570	5.4	1.0	5.40	9.6	1.6	15.36
18	GP-9472-4-13	5.2	1.1	5.72	10.6	1.4	14.84
19	AKSFI-46-2	5.4	1.0	5.40	6.6	1.0	6.60
20	TSG-195	2.4	1.0	2.40	6.6	1.2	7.92
21	TSG-196	8.4	1.0	8.40	6.8	1.2	8.16

Table 1. (cont.)

S.no	Germplasm	2016 -17			2017-18		
		Average No. of leafhoppers/ three leaves/plant	MSI	LHSI	Average No. of leafhoppers/ three leaves/plant	MSI	LHSI
22	TSG-197	2.0	0.6	1.20	4.4	1.0	4.40
23	TSG-198	3.8	0.8	3.04	4.2	1.0	4.20
24	TSG-216	5.6	1.1	6.16	8.2	1.2	9.84
25	TSG-217	2.8	0.6	1.68	3.2	0.8	2.56
26	TSG-238	8.4	1.1	9.24	11.6	1.2	13.92
27	TSG-258	4.6	1.4	6.44	6.8	1.6	10.88
28	TSG-278	5.8	1.1	6.38	8.2	1.4	11.48
29	TSG-287	6.6	1.2	7.92	9.6	1.6	15.36
30	TSG-295	11.4	2.6	29.64	18.2	2.8	50.96
31	TSG-296	6.0	1.1	6.60	8.2	1.4	11.48
32	TSG-297	6.4	1.3	8.32	8.4	1.6	13.44
33	TSG-298	3.4	0.8	2.72	4.6	1.0	4.60
34	TSG-302	10.4	1.2	12.48	12.4	1.4	17.36
35	TSG-320	5.6	1.1	6.16	8.6	1.3	11.18
36	TSG-337	6.8	1.1	7.48	7.4	1.4	10.36
37	TSG-338	6.4	1.2	7.68	9.6	1.4	13.44
38	TSG-339	6.8	1.1	7.48	7.8	1.3	10.14
39	TSG-349	0.3	0.6	0.18	2.6	1.0	2.60
40	TSG-400	2.1	1.0	2.10	3.8	1.2	4.56
41	TSG-401	3.8	0.8	3.04	6.2	1.0	6.20
42	TSG-HA-430-B	4.6	1.0	4.60	7.8	1.0	7.80

Table 1. (cont.)

S.no	Germplasm	2016 -17			2017-18		
		Average No. of leafhoppers/ three L-leaves/plant	MSI	LHSI	Average No. of leafhoppers/ three leaves/plant	MSI	LHSI
43	TSG-HA-89-B	6.0	1.0	6.00	10.6	1.0	10.60
44	PSCIM-115	8.6	1.2	10.32	13.6	1.8	24.48
45	PSCIM-117	13.2	1.8	23.76	17.2	2.3	39.56
46	PSCIM-122	10.4	1.6	16.64	13.8	2.2	30.43
47	PSCIM-186	12.6	2.6	32.76	20.2	3.2	64.64
48	PSCIM-137	6.6	1.6	10.56	14.0	2.4	33.60
49	PSCRM-127	10.4	2.6	27.04	17.8	2.7	48.06
50	PSECO-70	12.0	2.2	26.40	16.4	2.8	45.92
51	PSECO-79	12.6	2.7	34.02	24.2	3.0	72.60
52	PSECO-81	7.8	2.6	20.28	15.0	2.8	42.00
53	PSECO-86	15.6	3.0	46.80	23.4	3.4	79.56
54	PSERM-138	8.4	2.6	21.84	14.6	2.8	40.88
55	PSMO-53-B-1	15.0	2.7	40.50	20.6	3.5	72.10
56	PSMO-53-D	9.6	2.7	25.92	13.2	2.8	36.86
57	OCRM	7.8	1.2	9.36	8.4	1.8	15.12
58	Syngenta-SB-275	10.4	2.6	27.04	15.8	3.0	47.40
59	Morden (SC)	18.2	3.2	58.24	32.4	3.4	110.16
	Mean	7.3	-	-	11.0	-	-

Syngenta-SB-275 and susceptible check, Morden were found 'susceptible' to leafhoppers with an average MSI of 2.6 and 3.2, respectively. LHSI ranged between 0.18 and 58.24 among the germplasm lines wherein TSG- 349 recorded the lowest LHSI of 0.18 followed by TSG-197 (1.20), TSG-217 (1.68), GMU-339 (1.98), TSG-400 (2.10), GMU-669 (2.20), TSG-195(2.40), TSG-298 (2.72), GMU-696 (2.90), GMU-25 (3.00), TSG-198 and TSG-401 (3.04). Highest LHSI was recorded in susceptible check, Morden (58.24) followed by PSECO-86 (46.80) and PSMO-53-B-1 (40.50). The LHSI of remaining 43 accessions ranged between 4.20 and 34.02.

***Rabi*, 2017-18**

The leafhopper infestation ranged between 2.2 and 32.4 per three leaves per plant (Table 1). The germplasm accession, GMU-339 recorded the lowest mean population of leafhoppers (2.2 per three leaves per plant). The highest numbers of leafhoppers were recorded on the susceptible check, Morden (32.4 per three leaves per plant) followed by PSECO-79 (24.2 per three leaves per plant) and PSECO-86 (23.4 per three leaves per plant). The population of leafhopper in the remaining 54 accessions ranged between 2.6 and 20.6 per three leaves per plant. Fifteen germplasm accessions were categorized as 'resistant' with an MSI of 0.8 and 1.0; thirty germplasm lines were categorized as 'moderately resistant' with an average MSI ranging from 1.2 and 2.4 and twelve as susceptible with an MSI ranging from 2.6 and 3.5. The commercial sunflower hybrid, Syngenta-SB-275 and susceptible check, Morden were found to be 'susceptible' to leafhoppers with an average MSI of 3.0 and 3.4. LHSI ranged between 1.76 to 110.16, among the germplasm accessions, GMU-339 recorded the lowest LHSI of 1.76 followed by TSG- 217 (2.56), TSG- 349 (2.60), GMU-25 (3.40), TSG-198 (4.20), TSG-197 (4.40), TSG-298 (4.60), TSG-400 (4.56), GMU-669 (4.60), GMU- 696 (5.20), GMU-776 (5.40) and TSG-401 (6.20). Highest LHSI was recorded in susceptible check, Morden (110.16) followed by PSECO-86 (79.56), PSECO-79 (72.60) and PSMO-53-B-1 (72.10). The LHSI of remaining 43 accessions ranged between 6.60 and 64.64.

A perusal of Table 2 revealed that among the 57 accessions evaluated, fifteen accessions were consistently found resistant to leafhopper for two years, *i.e.,* 2016-17 and 2017-18. Twenty three accessions were offered moderate resistance while eleven accessions were found susceptible. However, eight accessions did not exhibit any consistency in their reaction to leafhoppers. Screening and evaluation of different germplasm accessions of sunflower against leafhopper was done earlier based on 0-5 injury grades by different workers *viz*., Saleem *et al.* (2017) and Ingale *et al.* (2019). Host plant resistance to leafhopper is being exploited as several research centres and important sources of resistance have been identified. Previous studies reported GMU-339 and TSG-401 resistance to leafhopper infestation based upon

Table 2. Categorization of sunflower germplasm based on mean scale index

2016-17	2017-18	2016-17 and 2017-18	Reaction
GMU-25, GMU-339, GMU-504,GMU-595 GMU-669,GMU-696, GMU-776, GMU-922, GMU-1029, GP-6-570, AKSFI-46-2, TSG-195, TSG-196, TSG-197, TSG-198, TSG-217, TSG-298, TSG-349, TSG-400, TSG-401, TSG-HA-430-B and TSG-HA-89-B	GMU-25, GMU-339, GMU-504, GMU-669, GMU-696, GMU-776, AKSFI-46-2, TSG-197, TSG-198, TSG-217, TSG-298, TSG-349, TSG-401, TSG-HA-430-B and TSG-HA-89-B	GMU-25, GMU-339, GMU-504, GMU-669, GMU-696, GMU-776, AKSFI-46-2, TSG-197, TSG-198, TSG-217, TSG-298, TSG-349, TSG-401, TSG-HA-430-B and TSG-HA-89-B	Resistant
GMU-4, GMU-327, GMU-343, GMU-405, GMU-556, GMU-713, GP-9472-4-13, TSG-216, TSG-238, TSG-258, TSG-278, TSG-287, TSG-296, TSG-297, TSG-302, TSG-320, TSG-337, TSG-338, TSG-339, PSCIM-	GMU-327, GMU-343, GMU-405, GMU-556, GMU-595, GMU-713, GMU-922, GMU-1029, GP-6-570, GP-9472-4-13, TSG-195, TSG-196, TSG-216, TSG-238, TSG-258,	GMU-327, GMU-343, GMU-405, GMU-556, GMU-713, GP-9472-4-13, TSG-216, TSG-238, TSG-258, TSG-278, TSG-287, TSG-296, TSG-297, TSG-302, TSG-320, TSG-337, TSG-338, TSG-339, PSCIM-115,	Moderately Resistant

2016-17	2017-18	2016-17 and 2017-18	Reaction
115, PSCIM-117, PSCIM-122, PSCIM-137, PSECO-70 and OCRM	TSG-278, TSG-287, TSG-296, TSG-297, TSG-302, TSG-320, TSG-337, TSG-338, TSG-339, TSG-400, PSCIM-115, PSCIM-117, PSCIM-122, PSCIM-137 and OCRM	PSCIM-117, PSCIM-122, PSCIM-137 and OCRM	
GMU-243, TSG-295, PSCIM-186, PSCRM-127, PSECO-79, PSECO-81, PSECO-86, PSERM-138, PSMO-53-B-1, PSMO-53-D, Syngenta-SB-275 and Morden (Susceptible check)	GMU-4, GMU-243, TSG-295, PSCIM-186, PSCRM-127, PSECO-70, PSECO-79, PSECO-81, PSECO-86, PSERM-138, PSMO-53-B-1, PSMO-53-D, Syngenta – SB-275 and Morden (Susceptible check)	GMU-243, TSG-295, PSCIM-186, PSCRM-127, PSECO-70, PSECO-79, PSECO-81, PSECO-86, PSERM-138, PSMO-53-B-1, PSMO-53-D, Syngenta-SB-275 and Morden (Susceptible check)	Susceptible

hoppers injury grade (DOR, 2006 and IIOR, 2017 and 2019). Morden was categorised as the most susceptible variety to leafhopper and recorded highest number of leafhopper nymphs per leaf and maximum injury grade of 5.0 (DOR, 1999 and 2008, Jagadish *et al.*, 2004, Saritha *et al.*, 2008 and Suganthy and Uma, 2010). Vijay kumar *et al.* (2019) reported six accessions as resistant (GMU-25, GMU-339, GMU-504, GMU-922, GMU-570 and GP-9-472-4-13), 16 germplasms as moderately resistant *i.e.,* GMU-1, GMU-4, GMU-116, GMU-405, GMU-595, GMU-669, GMU-703, GMU-782, GMU-914, GMU-1029, GMU-243, GMU-327, GMU-556, GMU-696, GMU-776 and AKSFI-46-2.

CONCLUSION

The results of the present study showed that fifteen germplasm accessions *viz*., GMU-25, GMU-339, GMU-504, GMU-669, GMU-696, GMU-776, AKSFI-46-2, TSG-197, TSG-198, TSG-217, TSG-298, TSG-349, TSG-401, TSG-HA-430-B and TSG-HA-89-B were found consistently resistant during *Rabi*, 2016-17 and 2017-18. These identified sources of resistance can be utilized in the resistance breeding programme for the development of resistant cultivars against *A.biguttula biguttula*.

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Research Article
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SCREENING OF SELECTED RICE GENOTYPES FOR IDENTIFICATION OF RESISTANT DONOR LINES AGAINST BROWN PLANTHOPPER, *Nilaparvata lugens* (Stal)

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ABSTRACT

Fifty seven rice genotypes were screened following Standard Seedbox Screening Test (SSST), along with two resistant checks (PTB 33 and BM 71) and one susceptible check TN1 to assess the level of resistance to BPH infestation. The study was conducted at Rice Research Station, Hyderabad during 2019-2020.The test revealed that out of 57 rice genotypes, only three genotypes *viz.,* Magic 289, RP 2068-18-3-5 and RNR 28370 exhibited damage score (DS) ranging from 1 to 3 and were designated as resistant (R). Five genotypes *viz.,* Magic-88, Magic-179, IRUE 45, IRUE 52 and RNR 29325 exhibited moderate resistance to BPH. The rest of 49 genotypes, 37 genotypes were identified as moderately susceptible with damage score ranging between 5.1-7.0 while the remaining 12 genotypes were identified as susceptible with damage score of 7.1 to 8.9. Further investigations on the mechanisms of resistance such as antixenosis, antibiosis and tolerance are required to identity the best genotypes that could be used for developing BPH resistant / tolerant variety with desirable yield and quality traits.

Rice is a major staple food grain as well as a major source of carbohydrate and energy in the daily diet of an average Indian and demand for rice is likely to increase with an ever growing population of the country. More than 90 per cent of the world's rice is grown and consumed in Asia, where 60 per cent of the global population lives. It is cultivated in about 154 million hectares annually which is equivalent to 11 per cent of the world's cultivated land. Rice is affected by more than two hundred insect pests of which about a dozen are economically important (Litsinger, 2009) and brown plant hopper is one among them. Brown planthopper, is a phloem-sap-sucking insect pest of rice (Sogawa, 1982). Both nymphs and adults suck sap from the lower portion of the plant, which results in yellowing of leaves, reduction in tiller number, plant height, and finally results in unfilled grains. Feeding also causes reduction in chlorophyll and protein content of leaves followed by reduced rate of photosynthesis. In case of severe attack, it causes extensive plant mortality referred to as 'hopper burn' symptom. BPH also transmits rice grassy stunt virus (GSV) and ragged stunt virus (RSV) as a vector (Khush and Brar, 1991). In recent years, BPH infestations have increased across Asia, causing heavy yield losses in rice. As the popular rice varieties are susceptible to planthoppers, farmers are forced to depend solely on chemical pesticides for controlling this insect, which is expensive in terms of labour, cost and also pose environmental hazards. In addition, overuse of pesticides destroys the natural predators and leads to the development of insecticidal resistance as well as pest resurgence. The best alternative for managing the pest is to follow integrated pest management using two important components *viz.,* adoption of resistant or tolerant variety and secondly use of insecticides with different modes of action from time to time. In view of the importance of resistant and tolerant varieties in managing BPH it is has become essential to identify new sources of resistance with improved quality parameters so as to introgress the same into the high yielding varieties.

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MATERIAL AND METHODS

Mass Rearing of BPH

Mass rearing of BPH was done on BPH susceptible rice variety Taichung Native 1 (TN1). Pre-germinated seeds of TN1 were sown in three litres plastic pots (3-4 hills per pot) filled with fertilizer enriched soil, and watered regularly in poly-house till plants reached 60 days of age. These plants were then transferred to insect proof rearing cages (5-6 pots per cage) and inoculated with 12-15 gravid females per cage and watered regularly. After the establishment of BPH population on TN1 the second and third instar nymphs that were emerged from this parent culture were collected and used in screening studies.

Screening

A total of 60 rice genotypes including a susceptible check (TN1) and a resistant check PTB33 and BM71 were screened against BPH using the Standard Seedbox Screening Test (SSST) developed by the International Rice Research Institute (IRRI), (Heinrichs *et al.,* 1985). The seeds of selected genotypes were kept in separate petri plates and water poured till all the seeds got submerged in water. After 24 hours, the excess water was drained and seeds were kept for germination. After 48 hours, the pre germinated seeds were sown in plastic trays (42 x 32 x 15 cm) and labelled accordingly. The seeds were sown in the plastic trays in a specific layout (Figure 1) in which different treatments were planted randomly with help of a random number table while resistant checks PTB33 and BM71 were planted in the middle row and the susceptible check TN1, was planted around the perimeter of the rectangular tray. Each rice entry was replicated thrice. A maximum of 20 rice genotypes excluding the resistant and susceptible checks were planted in SSST tray. Three such trays were required to conduct the experiment with 57 genotypes and these were replicated thrice so a total of nine SSST trays were used for screening. Seedlings were watered regularly and allowed to grow healthy till three leaf stage in rearing cages. On reaching three leaf stages, seedlings were infested with 2nd and 3rd instar BPH nymphs @ 7-8 nymphs/ seedling. BPH infected seedlings were kept in rearing cages and the water level was maintained uniformly throughout the tray. The tray was also rotated 180Ú at regular intervals to ensure uniform reaction to BPH. Once 90 per cent mortality was observed in seedlings of susceptible check (TN1), the damage score was recorded based on a 0-9 scale using the Standard Evaluation System (SES) [IRRI, 2014] as described in Table1. After scoring as per SES, means damage score of three replications was calculated. All the SSST entries were then categorized as resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S) and highly susceptible (HS) based on damage score, as suggested by Jegadeeswaran *et al.*, 2014 (Table 2).

Figure1. Layout of Standard Seedbox Screening Test (SSST)

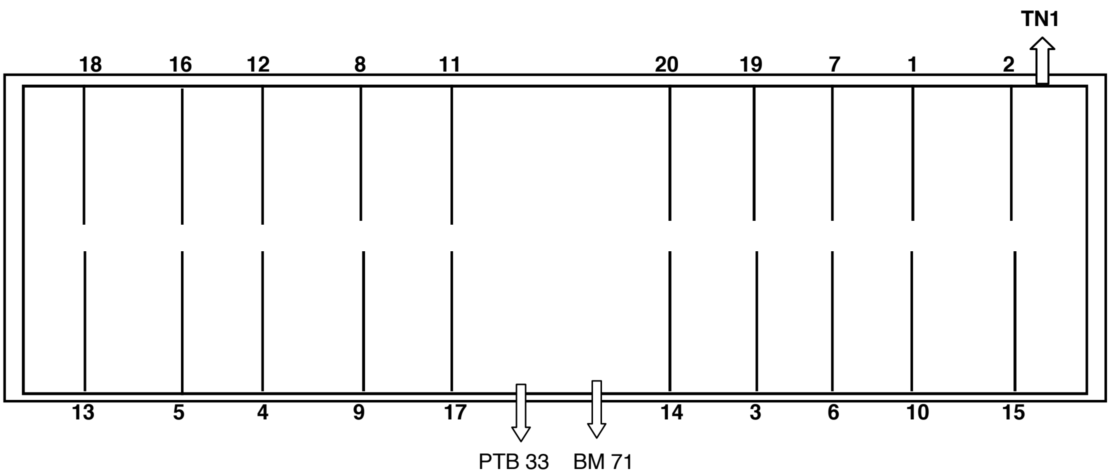

Table 1. Standard Evaluation System (SES) describing the score of plant based on its Reaction to BPH incidence

Plant state	Score
No damage	0
Very slight damage	1
Lower leaf wilted with two green upper leaves	3
Two lower leaves wilted with one green upper leaf	5
All three leaves wilted but stem still green	7
Plant is dead	9

Table 2. Categorization of levels of resistance based on damage score

S.No	Reaction	Damage score
1	Resistant (R)	1.0 - 3.0
2	Moderately Resistant (MR)	3.1 - 5.0
3	Moderately Susceptible (MS)	5.1 - 7.0
4	Susceptible (S)	7.1 -8.9
5	Highly Susceptible (HS)	9.0

RESULTS AND DISCUSSION

Results pertaining to screening of 57 rice genotypes revealed that only three genotypes *viz.,* Magic line-16, RP2068-18-3-5 and RNR 28370 were found resistant to brown planthopper with their damage score ranging between 1-3. The three genotypes exhibited damage scores on par with two resistant checks PTB33, BM71 while the genotype Magic line-16 was found to show more resistance compared to PTB33 and BM71 (Table-3). It was also found during the screening that five genotypes exhibited damage score (DS) ranging between 3.1 to 5 which include Magic line-2, Magic line-6, IRUE 45, IRUE 52 and RNR 29325. These five genotypes were designated as moderately resistant (MR) to BPH. The rest of the 49 genotypes were found susceptible with a damage score of >5. Among the 49 genotypes, 37 genotypes were identified as moderately susceptible with damage score ranging between 5.1-7.0 while the remaining 12 genotypes were identified as susceptible with damage score of 7.1 to 8.9.

It is evident from the investigation that the three resistant rice genotypes showed resistance characteristics on par with that of PTB33 and BM71 can be a good source of resistance for breeding BPH resistance varieties. Bhogadhi *et al.* (2015) reported that rice cultivars MTU 1001 which recorded damage score in the range of 3.0 to 4.0. Standard Seedbox Screening Test (SSST) also exhibited moderate resistance or tolerant activity under field conditions. Nikil Raj *et al.,* (2019) screened 61 rice genotypes and reported none to be resistant but found 12 genotypes *viz.,* Milyang 63, IET 23993, HHZ 5 DT-1 DT-1, HHZ 25 SAL DT-1DT-1, Bobhu Kongbu, BPT 2671, BPT 2611, MTU 1121, MTU 1001, MTU 1010, RNR 23079 and GSR 234 as moderately resistant to BPH and suggested their use in breeding programme. Similarly, Udayasree *et al.,* (2018) worked with 39 rice genotypes and found none of the genotypes as resistant to BPH but identified 17 genotypes as moderately resistant to BPH. She has further suggested only two genotypes *viz.,* KNM 2305 and RNR 21571 as suitable for breeding programme after analyzing the antixenosis, antibiosis and tolerance mechanisms responsible for resistance. Based on present studies it can be recommended that the five moderately resistant genotypes can also be used as a source of resistance for breeding for resistance against BPH after confirming through genetic studies. Identification of new sources of resistance against brown planthopper *Nilaparvata lugens* is continuous process to combat the problem of biotypes and also to find out sources with multiple resistances.

Further, a detailed investigation on the mechanisms that are governing host plant resistance in the identified eight genotypes is essential to elucidate the information regarding the type of resistance *viz.* antixenosis, antibiosis, and tolerance. Proper and scientific use of this data will lead to the development of resistant sources against BPH.

Table 3. Reaction of different rice cultures against BPH

S.No	Rice Genotype	Mean Damage Score	Score
1	MAGIC LINE-1	8.0	S
2	MAGIC LINE-2	3.2	MR
3	MAGIC LINE-3	5.8	MS
4	MAGIC LINE-4	5.7	MS
5	MAGIC LINE-5	6.8	MS
6	MAGIC LINE-6	4.4	MR

Table 3 (cont.)

S.No	Rice Genotype	Mean Damage Score	Score
7	MAGIC LINE-7	6.9	MS
8	MAGIC LINE-8	5.5	MS
9	MAGIC LINE-9	6.3	MS
10	MAGIC LINE-10	5.8	MS
11	MAGIC LINE-11	5.9	MS
12	MAGIC LINE-12	6.1	MS
13	MAGIC LINE-13	5.6	MS
14	MAGIC LINE-14	6.4	MS
15	MAGIC LINE-15	6.1	MS
16	MAGIC LINE-16	1.7	R
17	MAGIC LINE-17	8.1	S
18	MAGIC LINE-18	8.1	S
19	MAGIC LINE-19	8.4	S
20	KNM 7048	5.6	MS
21	KNM 7715	5.7	MS
22	KNM 7777	5.3	MS
23	JGL 32429	7.5	S
24	JGL 33016	7.1	S
25	JGL 33124	5.8	MS
26	WGL 1246	5.2	MS
27	RNR 28361	6.1	MS
28	RNR 28373-1	5.2	MS
29	RNR 28403	7.3	S
30	RNRH-68	5.3	MS
31	RNRH 95	7.6	S
32	IRUE 13	5.1	MS
33	IRUE 28	5.1	MS
34	IRUE 45	3.4	MR
35	IRUE 52	3.5	MR
36	RDR 1210	7.5	S
37	JGL 34564	6.1	MS
38	MLTE-22	6.2	MS
39	MLTM-16	6.7	MS
40	BPT-3111	6.1	MS
41	CB-15-138	6.2	MS
42	KNM 7777	5.1	MS
43	KNM 7786	5.4	MS
44	KNM 7787	5.1	MS
45	MTU 1307	5.5	MS
46	MTU 1308	5.7	MS
47	RNR 26121	5.3	MS
48	RNR 28370	2.6	R
49	RNR 28371-1	5.1	MS
50	RP2068-18-3-5	2.7	R
51	RP 122-10-3-1	7.2	S
52	RNR 29197	5.8	MS
53	RNR 29325	3.4	MR
54	RNR 11718	5.2	MS
55	RNR 15048	7.7	S
56	MTU 1001	5.3	MS
57	MTU 1010	8.5	S
58	TN1 (Susceptible check)	9.0	HS
59	PTB-33 (Resistant check)	2.4	R
60	BM71 (Resistant check)	2.5	R

R - Resistant, MR - Moderately Resistant, MS - Moderately Susceptible,
S - Susceptible, HS - Highly Susceptible

CONCLUSION

The test revealed that out of 57 rice genotypes, only three genotypes *viz.,* Magic 289, RP2068-18-3-5 and RNR 28370 exhibited as resistant (R). Five genotypes *viz.,* Magic-88, Magic-179, IRUE 45, IRUE 52 and RNR 29325 exhibited moderate resistance to BPH and remaining genotypes which was exhibited as moderately susceptible and susceptible genotypes along with two resistant checks (PTB 33 and BM71) and one susceptible check TN1.

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Research Article
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INFLUENCE OF SEQUENTIAL INTERCROPPING SYSTEMS AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH PARAMETERS AND SEED YIELD OF PIGEONPEA

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ABSTRACT

An experiment was carried out during *kharif* and *rabi* seasons of 2019-20 and 2020-21 at ARI, Rajendranagar, Hyderabad. The experiment was laid out in randomized block design (Factorial) with two factors *i.e.*, one with six levels of sequential intercropping systems of pigeonpea (S_1 to S_6) and other with two levels of nutrient management practices (N_1 and N_2 - an integrated approach). Initial and final plant population were recorded at 30 DAS and harvest, respectively. Growth observations of pigeonpea *viz*., plant height, leaf area plant^{-1}, dry matter production plant^{-1} and number of branches plant^{-1} were recorded at periodical intervals. Initial and final plant population were significantly not influenced by sequential intercropping systems and integrated nutrient management practices. Among the pigeonpea based sequential intercropping systems higher plant height, leaf area plant^{-1}, dry matter production plant^{-1}, number of branches plant^{-1} and seed yield were recorded when pigeonpea sown as sole (S_1 and S_2) than the pigeonpea with sequential intercropping systems (S_3, S_4, S_5 and S_6) during both the years. However, higher pigeonpea equivalent yield was recorded in paired row pigeonpea with sweet corn – chickpea (S_5). Application of 75 % RDN through fertilizers and 25 % through FYM (N_2) recorded higher plant height, leaf area plant^{-1}, dry matter production plant^{-1}, number of branches plant^{-1}, seed yield and pigeonpea equivalent yield over application of 100 % RDN through fertilizers (N_1).

Pigeonpea (*Cajanus cajan* (L.) Millsp., syn. *Cajanus indicus* Spreng), also known as arhar, tur, pigeonpea, congo-pea, no eye pea is the most important *kharif* season crop in India and second most important pulse crop after chickpea. The production of pigeonpea has increased over the years, from 1.72 million tonnes in 1950-51 to 4.25 million tonnes in 2017-18. The increase in production is a result of increase in area from 2.18 million hectares in 1950-51 to around 5.34 million hectares in 2016-17. However, the overall productivity of pigeonpea has remained between 637 to 655 kg ha^{-1} for last several decades (India Stat, 2019). The low yield of pigeonpea is not only due to its cultivation on sub-marginal lands, but also because of inadequate and imbalanced fertilization which decreased the productivity. Inspite of its importance in small hold economy, the crop has not received proper attention for possible yield improvement through management practices.

Intercropping of short duration crops in the inter space between two rows of a wide spaced crop like pigeonpea that initially grows slowly, can help in better resource utilization and stabilize crop productivity by reducing impact of weather vagaries and increase the cropping intensity (Marer*et al*., 2007).

Pigeonpea during *kharif* is generally sown in the month of June - July and it is harvested in the month of December - January. The intercrops sown in *kharif* season like sweet corn can be harvested in 80-85 days. Many Indian farmers after harvesting of intercrops of pigeonpea, keep the land vacant in between the rows of pigeonpea till the harvesting of pigeonpea. So, there is need to utilise that land for crop production by sowing again with some suitable crops. There is possibility of growing short duration and fast growing crops in between the rows of pigeonpea after the harvesting of *kharif* sown inter crops. This practice of sequential crops for *kharif* inter crops which are sequential inter cropping for pigeonpea is till now not noticed. Nutrient management is the basic factor and is found to exert a great influence not only on growth and yield attributes of crops but also for obtaining sustained productivity. Among all nutrients N, P, K are most important nutrients which contribute to proper

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growth and yield of crop plant and it also has direct effect on metabolism of plant. In intercropping system, intercrop has lower plant population than its sole crop thus higher dose of nutrients may be helpful in improving yield (Kumar and Kushwaha, 2018). Hence, present study was undertaken to see the feasibility of pigeonpea with intercropping of *kharif* and *rabi* season crops in order to make efficient utilization of natural resources under proper agronomic management for higher productivity of crops by limiting competition among the crops. So, it will be beneficial to the farmers by utilizing the land effectively with optimum inputs and harnessing higher income.

MATERIAL AND METHODS

An experiment carried out during *kharif* and *rabi* seasons of 2019-20 and 2020-21 at ARI, Rajendranagar, Hyderabad is located in the Southern agroclimatic zone of Telangana state. Geographically, it lies at 17^{0} 19' 24" N latitude and 78^{0} 23' 50" E longitude at an altitude of 523 m above mean sea level. During the crop growth period, a total rainfall of 708.8 mm received in 47 rainy days during 2019-20 and 1281.8 mm in 57 days during 2020-21. The daily mean bright sunshine during crop growth period ranged from 1.2 to 10.3 hours with an average of 6.1 hours in 2019-20 season while in 2020-21 season it was ranged from 0.6 to 9.4 hours with an average of 6.0 hours. The daily mean evaporation (mm) during the crop growth period was 3.6 mm during both 2019-20 and 2020-21 seasons.

The soil was clay in texture, slightly alkaline, low in organic carbon and available nitrogen, medium in available phosphorous and high in available potassium. Pigeonpea variety, TDRG 4 **(**Hanuma), sweet corn (Sugar-75), chickpea (NBeG 3) and safflower (Manjeera) were tested in this experiment.

The experiment was laid out in Randomized Block design (Factorial) with six sequential intercropping systems [S_1 - Pigeonpea (180 cm), S_2 - Paired row pigeonpea (60-300-60 cm) (With in pair 60 cm and in between pair 300 cm), S_3 - Pigeonpea + Sweetcorn – Chickpea, S_4 - Pigeonpea + Sweetcorn – Safflower, S_5 - Paired row pigeonpea + Sweetcorn – Chickpea and S_6 - Paired row pigeonpea + Sweetcorn– Safflower] and two nutrient management practices [N_1 - 100 % RDN and N_2 - 75 % RDN + 25 % N through FYM – an integrated approach] with three replications. Row ratio of pigeonpea and sweet corn in S_3 and S_4 was 1:2 and in S_5 and S_6 it was 2:4 ratio. Chickpea sown as sequential intercrop with pigeonpea in the ratio of 1:5 in S_3 and 2:9 in S_5. Safflower also sown as sequential intercrop with pigeonpea in S_4 and S_6 in the ratio of 1:2 and 2:4, respectively. For *kharif* season sown pigeonpea and sweetcorn the above mentioned INM treatments (N_1 and N_2) were applied based on plant population. For sequential intercrops, sown in *rabi* season only 75 % Recommended Dose of Nitrogen through fertilizers (RDN) on population basis was applied through straight fertilizers. Irrespective of treatments P and K were applied based on recommended dose on population basis. In pigeonpea, observations were recorded on plant population *viz*., initial and final at 30 DAS and harvest, respectively. Growth observations *viz*., plant height, leaf area plant^{-1}, dry matter production plant^{-1} and number of branches plant^{-1} were recorded at periodical intervals. Seed yield and pigeonpea equivalent yield were also recorded.

RESULTS AND DISCUSSION

Initial plant population

Plant population is the determinant of yield in any crop and it is the basis for the comparing the treatments applied. The number of pigeonpea plants per net plot area was counted at 30 DAS and it was converted to per hectare and presented in Table 1. The effect of sequential intercropping systems under integrated nutrient management on initial plant population (30 DAS) was shown statistically non-significance during both the years of study. The mean number of plants per hectare at initial stage of crop growth (30 DAS) were 26,582 and 26,839 during 2019-20 and 2020-21 seasons, respectively (Table 1).

Final plant population

The final pigeonpea plant population per net plot was counted at harvesting stage and it was converted to plant population per hectare. The individual and interaction effect of integrated nutrient management in different sequential intercropping systems on final plant population at harvest was shown statistically non-significant during both the years of study. The mean number of final plant population at harvest was 26,399 and 26,704 during 2019-20 and 2020-21 seasons, respectively (Table 1).

Table 1. Plant population (ha^{-1}) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	Initial Plant population ha^{-1}			Final Plant population ha^{-1}		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sequential intercropping systems (S)						
S_1 - Pigeonpea (180 cm)	26563	27241	26902	26389	27034	26712
S_2 - Paired row pigeonpea (60-300-60 cm)	26563	26736	26649	26360	26678	26519
S_3 - Pigeonpea + Sweetcorn - Chickpea	26736	26765	26751	26534	26620	26577
S_4 - Pigeonpea + Sweetcorn - Safflower	26447	26910	26678	26273	26707	26490
S_5 - Paired row pigeonpea + Sweetcorn - Chickpea	26649	26563	26606	26505	26476	26490
S_6 - Paired row pigeonpea + Sweetcorn - Safflower	26534	26823	26678	26331	26707	26519
S.Em±	768.45	714.69	-	755.35	635.31	-
CD (p=0.05)	NS	NS	-	NS	NS	-
Integrated nutrient management (N)						
N_1 - 100 % RDN	26447	26775	26611	26379	26659	26519
N_2 - 75 % RDN + 25 % N through FYM	26582	26904	26743	26418	26749	26583
S.Em±	443.67	412.63	-	436.10	366.79	-
CD (p=0.05)	NS	NS	-	NS	NS	-
Interactions(SxN)						
S.Em±	1086.75	1010.73	-	1068.23	898.46	-
CD (p=0.05)	NS	NS	-	NS	NS	-
General Mean	26582	26839	26711	26399	26704	26551
CV (%)	7.08	6.52	-	7.01	5.83	-

RDN - Recommended dose of nitrogen through fertilizers; FYM - Farm Yard Manure

Plant height

Plant height (cm) is a straight indicator to quantify the growth and development of the plant. Plant height of any crop governs or changes the yield attributing characters and eventually the yield of the crop. Plant height of pigeonpea was increased slow during the initial stage (up to 30 DAS) and increased linearly up to 120 DAS and increased at diminishing rate till plant get matured. The average plant height was 26.00, 91.59, 136.11, 163.38 and 169.11 cm at 30, 60, 90, 120 DAS and at harvest, respectively (Table 2).

The data revealed that, the plant height was not significantly influenced by the sequential intercropping systems up to 30 DAS during both the years of study. It indicates that during the initial crop growth period of pigeonpea, plant height was not affected by the component crop sweet corn as plants were little enough to compete for the space (Saritha *et al*. 2012). However, from 60 DAS to harvest, plant height was significantly influenced by the sequential inter cropping systems.

Significantly maximum plant height was recorded at harvest in sole pigeonpea (S_1) (185.63 and 197.95 cm) and which was on par with the paired row pigeonpea (S_2) (184.03 and 190.20 cm) during 2019-20 and 2020-21, respectively. The minimum plant height was recorded in paired row pigeonpea with sweet corn – safflower (S_6) (146.93 and 146.01 cm) which was on par with the paired row pigeonpea with sweet corn – chickpea (S_5) (150.63 and 150.48 cm) during 2019-20 and 2020-21, respectively. Sequential

Table 2 . Plant height (cm) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	30 DAS			60 DAS			90 DAS		
	19-20	20-21	Mean	19-20	20-21	Mean	19-20	20-21	Mean
Sequential intercropping systems (S)									
S_1 - Pigeonpea (180 cm)	26.56	28.24	27.40	99.40	107.14	103.27	149.80	158.26	154.03
S_2 - Paired row pigeonpea (60-300-60 cm)	25.97	28.61	27.29	98.40	105.91	102.16	147.37	152.86	150.11
S_3 - Pigeonpea + Sweetcorn – Chickpea	25.03	26.40	25.72	88.83	94.51	91.67	134.40	138.06	136.23
S_4 - Pigeonpea + Sweetcorn – Safflower	24.97	26.14	25.55	88.07	91.18	89.62	134.30	136.39	135.35
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	24.54	25.37	24.95	78.47	85.22	81.84	121.63	120.64	121.14
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	24.39	25.76	25.07	77.80	84.13	80.96	120.60	119.06	119.83
S.Em±	0.95	1.05		2.89	3.22	-	4.18	4.80	-
CD (p=0.05)	NS	NS		8.47	9.45	-	12.25	14.07	-
Integrated nutrient management(N)									
N_1 - 100 % RDN	24.74	25.99	25.36	86.01	90.49	88.25	130.78	133.31	132.04
N_2 - 75 % RDN + 25 % N through FYM	25.74	27.51	26.63	90.98	98.87	94.93	138.59	141.78	140.18
S.Em±	0.55	0.61		1.67	1.86	-	2.41	2.77	-
CD (p=0.05)	NS	1.79		4.89	5.46	-	7.07	8.12	-
Interactions(SxN)									
S.Em±	1.35	1.49		4.09	4.56	-	5.91	6.78	-
CD (p=0.05)	NS	NS		NS	NS	-	NS	NS	-
General Mean	25.24	26.75	26.00	88.49	94.68	91.59	134.68	137.55	136.11
CV (%)	9.23	9.65		8.00	8.34	-	7.60	8.54	-

RDN - Recommended dose of nitrogen through fertilizers; FYM - Farm yard manure

intercropping of pigeonpea + sweet corn – chickpea (S_3) (169.40 and 171.67 cm) and pigeonpea + sweet corn – safflower (S_4) (167.63 and 168.81 cm) were recorded higher plant height than sequential intercropping in paired row pigeonpea with sweet corn – chickpea (S_5) (150.63 and 150.48 cm) and paired row pigeonpea with sweet corn – safflower (S_6) (146.93 and 146.01 cm) during 2019-20 and 2020-21, respectively.

The higher plant height of sole pigeonpea (S_1 and S_2) than pigeonpea with sequential inter cropping systems (S_3, S_4, S_5 and S_6) and in S_3 and S_4 than S_5 and S_6 may be due to competition among the inter and intra row plants for the resources *viz*., light and nutrients which are promote the vertical growth of the plant rather than horizontal (Singh, 2017). It also might be due to plant population per unit area was higher in intercropping than the sole cropping (Roddannavar, 2008). Similar findings were also reported by Singh and Pal (2003) and Pramila Rani and Reddy (2010).

Plant height of pigeonpea was shown statistically significant difference between nutrient management practices *i.e.*, 100% RDN through fertilizers (N_1) and 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) – an integrated approach at all the crop growth stages under study during both the years (2019-20 and 2020-21) except 30 DAS where it was not significant. At harvest, application of 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) recorded maximum plant height (172.03 and 176.63 cm) than 100 % RDN through fertilizers (N_1) (162.72 and 165.07 cm) during 2019-20 and 2020-21, respectively. The per cent enhance in plant height at harvest with 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) was recorded 5.72 and 7.00 per cent higher than 100 % RDN through fertilizers (N_1) during 2019-20 and 2020-21, respectively. Higher plant height of pigeonpea in N_2 over N_1 might be due to mixed application of inorganic and organic form of nutrient sources in N_2 that might be ascribed the improved availability of macro and micro nutrients and better physical condition of soil to uptake more nutrients from the soil resulting higher vegetative growth. Higher nutrient uptake may also lead to the increased cell division and elongation ensued the increased plant height of pigeonpea. These findings were inline with the findings of Sharma *et al.* (2009) and Shete *et al.* (2010).

Leaf area plant^{-1}

Regardless of treatments, leaf area plant^{-1} of pigeonpea crop increased up to 120 DAS and thereafter it decreased because of leaf drop till crop get matured. The mean leaf area plant^{-1} were 133.56, 1260.16, 2098.30, 6674.89 and 1759.21 cm^2 at 30, 60, 90, 120 DAS and at harvest, respectively. The leaf area plant^{-1} of pigeonpea crop as influenced by sequential intercropping systems under integrated nutrient management during both the years of study (2019-20 and 2020-21) (Table 3). At all the growth stages, leaf area plant^{-1} of pigeonpea crop was significantly influenced by the sequential inter cropping systems and maximum leaf area plant^{-1} was recorded in sole pigeonpea (S_1) and which was on par with paired row pigeonpea (S_2) over pigeonpea sown with intercrops (S_3, S_4, S_5 and S_6), during both the years of study.

Significantly maximum leaf area plant^{-1} was recorded at 120 DAS in sole pigeonpea (S_1) (7565.75 and 7853.60 cm^2) and which was on par with the paired row pigeonpea (S_2) (7376.36 and 7619.01 cm^2) during 2019-20 and 2020-21, respectively. The minimum leaf area was recorded in treatments with sequential intercropping in paired row pigeonpea with sweet corn – safflower (S_6) (5461.04 and 5974.11 cm^2) which was on par with the sequential intercropping in paired row pigeonpea + sweet corn – chickpea (S_5) (5522.06 and 6040.45 cm^2) during 2019-20 and 2020-21, respectively. The higher leaf area of sole pigeonpea (S_1 and S_2) than pigeonpea with sequential inter crops (S_3, S_4, S_5 and S_6) may be due to fair availability of growth substances *viz*., nutrients, water, solar radiation and space. When plants are widely spaced, they tend to develop higher number of branches with well spreading owed to enhanced accessibility of solar radiation and space (Saritha *et al.*, 2012). Higher number of plants m^{-2} in the inter cropping systems lead to higher growth stress result in huge loss of lower leaves from the plants. Higher leaf area plant^{-1} of pigeonpea when sown sole also might be due to enhanced and balanced availability of nutrients lead to the speedy cell division and meristematic tissue enlargement. Sequential intercropping of pigeonpea + sweet corn – chickpea (S_3) (6573.21 and 6912.33 cm^2) and pigeonpea + sweet corn – safflower (S_4) (6473.41 and 6727.33 cm^2) were recorded higher leaf area plant^{-1}

Table 3. Leaf area plant^{-1} (cm^2) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	30 DAS			60 DAS			90 DAS		
	19-20	20-21	Mean	19-20	20-21	Mean	19-20	20-21	Mean
Sequential intercropping systems (S)									
S_1 - Pigeonpea (180 cm)	140.91	155.14	148.02	1372.37	1500.54	1436.46	2264.36	2504.02	2384.19
S_2 - Paired row pigeonpea (60-300-60 cm)	141.01	153.65	147.33	1325.12	1472.30	1398.71	2244.92	2458.22	2351.57
S_3 - Pigeonpea + Sweetcorn – Chickpea	128.49	137.71	133.10	1204.55	1306.80	1255.67	2050.40	2180.10	2115.25
S_4 - Pigeonpea + Sweetcorn – Safflower	126.53	139.39	132.96	1193.54	1315.05	1254.29	2027.06	2162.37	2094.71
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	115.06	125.48	120.27	1076.02	1139.80	1107.91	1765.71	1908.96	1837.33
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	112.31	127.09	119.70	1068.41	1147.47	1107.94	1718.60	1894.90	1806.75
S.Em±	3.65	5.56	-	38.97	53.84	-	58.11	71.90	-
CD (p=0.05)	10.71	16.29	-	114.29	157.93	-	170.43	210.88	-
Integrated nutrient management (N)									
N_1 - 100 % RDN	122.32	133.71	128.02	1169.03	1262.80	1215.92	1941.27	2070.44	2005.85
N_2 - 75 % RDN + 25 % N through FYM	132.45	145.78	139.11	1244.30	1364.52	1304.41	2082.41	2299.08	2190.75
S.Em±	2.11	3.21	-	22.50	31.09	-	33.55	41.51	-
CD (p=0.05)	6.18	9.41	-	65.99	91.18	-	98.40	121.75	-
Interactions (SxN)									
S.Em±	5.16	7.86	-	55.11	76.15	-	82.18	101.68	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	127.38	139.74	133.56	1206.67	1313.66	1260.16	2011.84	2184.76	2098.30
CV (%)	7.02	9.74	-	7.91	10.04		7.07	8.06	

RDN - Recommended dose of nitrogen through fertilizers; FYM-Farm yard manure

Table 3 (cont.). Leaf area plant^{-1} (cm^2) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	120 DAS			At Harvest		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sequential intercropping systems (S)						
S_1 - Pigeonpea (180 cm)	7565.75	7853.60	7709.67	2354.33	2401.83	2378.08
S_2 - Paired row pigeonpea (60-300-60 cm)	7376.36	7619.01	7497.68	2145.08	2273.75	2209.42
S_3 - Pigeonpea + Sweetcorn – Chickpea	6573.21	6912.33	6742.77	1635.17	1853.38	1744.27
S_4 - Pigeonpea + Sweetcorn – Safflower	6473.41	6727.33	6600.37	1569.75	1555.60	1562.68
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	5522.06	6040.45	5781.25	1296.10	1523.78	1409.94
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	5461.04	5974.11	5717.57	1189.52	1312.23	1250.87
S.Em±	214.48	225.32	-	80.62	91.34	-
CD (p=0.05)	629.08	660.88	-	236.47	267.90	-
Integrated nutrient management (N)						
N_1 - 100 % RDN	6250.84	6570.82	6410.83	1448.06	1613.03	1530.54
N_2 - 75 % RDN + 25 % N through FYM	6739.76	7138.11	6938.94	1948.59	2027.16	1987.88
S.Em±	123.83	130.09	-	46.55	52.73	-
CD (p=0.05)	363.20	381.56	-	136.53	154.67	-
Interactions (SxN)						
S.Em±	303.32	318.65	-	114.02	129.17	-
CD (p=0.05)	NS	NS	-	NS	NS	-
General Mean	6495.30	6854.47	6674.89	1698.33	1820.09	1759.21
CV (%)	8.09	8.05	-	11.63	12.29	-

RDN - Recommended dose of nitrogen through fertilizers; FYM - Farm yard manure

than sequential intercropping in paired row pigeonpea with sweet corn – chickpea (S_5) (5522.06 and 6040.45 cm^2) and paired row pigeonpea with sweet corn – safflower (S_6) (5461.04 and 5974.11 cm^2) at 120 DAS during 2019-20 and 2020-21, respectively. Similar findings were also reported by Singh and Pal (2003).

Leaf area plant^{-1} of pigeonpea crop was statistically comparable between nutrient management practices *i.e.*, 100 % RDN through fertilizers (N_1) and 75% RDN through fertilizers + 25 % RDN through FYM (N_2) at all the crop growth stages during both the years under study. The leaf area plant^{-1} was recorded maximum at 120 DAS in treatment in which application of 75% RDN through fertilizers + 25 % RDN through FYM (N_2) (6739.76 and 7138.11 cm^2) over application of 100 % RDN through fertilizers (N_1) (6250.84 and 6570.82 cm^2) during 2019-20 and 2020-21, respectively. Combined application of organic and inorganic form of fertilizers increased the cell metabolism that lead to the enhanced growth and finally the leaf area. Nitrogen is an important structural element of the protein, which is the building material or protoplasm of each cell of the organism. Nitrogen also an important compound in chlorophyll which imparts the green colour to the leaves. So increased availability of nitrogen to pigeonpea from the soil may be enhanced the amount of amino acids, proteins and chlorophyll formation finally led to the increased number of leaves and leaf area plant^{-1}(Singh, 2017) in N_2 through enhanced cell division. These findings were in line with the findings of Sharma *et al.* (2009), Reddy *et al.* (2011) and Singh (2017).

Dry matter production

Higher dry matter production is important to get higher yields. In any crop, the quantity of dry matter produced is mainly depends on the photosynthetic efficiency and respiration. The gross dry matter production is equal to the gross amount of dry matter produced in the photosynthesis process minus the amount of photosynthates used in respiration process. So, the economical yield of the crop is determined by the distribution of net dry matter to the different parts of the plant (Arnon, 1972).

Increase in average dry matter production of pigeonpea was relatively slow up to 60DAS (9.19 and 11.55g plant^{-1} in 2019-20 and 2020-21, respectively), thereafter it increased linearly up to 120 DAS (87.45 and 95.43 g plant^{-1} in 2019-20 and 2020-21, respectively) and further, it was continue to enhance until the crop maturity (127.60 and 140.90 g plant^{-1} in 2019-20 and 2020-21, respectively) at a decreasing rate during both the years. The dry matter production of pigeonpea crop was influenced by sequential intercropping systems under integrated nutrient management at 30, 60, 90, 120 DAS and at harvest during both the years of study (Table 4). Paired row pigeonpea + sweet corn – safflower (S_6) recorded significantly lower dry matter production of pigeonpea and which was on par with the paired row pigeonpea + sweet corn – chickpea (S_5) at all the growth stages as compared to all other systems during both the years of study. At all the growth stages, maximum dry matter production was recorded in sole pigeonpea (S_1) and which was on par with the paired row pigeonpea (S_2) during 2019-20 and 2020-21, respectively. At harvest also, maximum dry matter production was recorded in sole pigeonpea (S_1) (150.20 and 167.09 g plant^{-1}) and which was on par with the paired row pigeonpea (S_2) (142.93 and 158.52 g plant^{-1}) during 2019-20 and 2020-21, respectively. Sole pigeonpea (S_1) recorded 36.05 and 39.17 percent higher dry matter production than sequential intercropping system in paired row pigeonpea + sweet corn – safflower (S_6) (108.73 and 118.62 g plant^{-1}) at harvest during 2019-20 and 2020-21, respectively. This was attributed to the better availability of growth resources like moisture, space, nutrients, light etc. The lower dry matter production of pigeonpea with inter cropped treatments may be due to the fact that the pigeonpea plants covered by the sweet corn from both the sides of each row because of additive inter cropping of sweet corn with the pigeonpea. This may increase the competition among the intercrops for growth substances *viz.*, space, light, water etc. The restricted development finally imparts on decreased leaf area, photosynthesis and finally dry matter production. Similar findings were also reported by Singh and Pal (2003).

Dry matter production in pigeonpea is generally depends on the plant height, number of branches, leaf area and its tenacity at vegetative period and during the reproductive phase, it depends up on number of pods, number seeds pod^{-1}, test weight and dry matter accumulation to these sinks (Baligar and Fageria, 2007). Therefore, it indicates the dry matter accumulation not only before the pod initiation but also during the pod filling and seed development decides the dry matter production and finally it represents the photosynthetic size and yield capability of the plant (Austin, 1982).

Dry matter production plant^{-1} of pigeonpea crop was statistically comparable between nutrient management practices *i.e.*, 100 % RDN through fertilizers (N_1) and 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) at all the crop growth stages during both the years under study. The dry matter production plant^{-1} was higher in 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) (132.19 and 145.36 g plant^{-1}) than100 % RDN through fertilizers (N_1) (123.39 and 136.44 g plant^{-1}) at harvest during 2019-20 and 2020-21, respectively. Higher dry matter production in N_2 over N_1 was may be due to integrated use of organic and inorganic form of nutrients enhanced the availability of nutrients along with the increased availability of micronutrients, hormones and enzymes. This leads to the increased number of branches, leaf area resulting enhanced photo accumulation. Finally, it imparts more dry matter production. Therefore, it is imperative that integrated nutrient management can be made essential factor to enhance dry matter production of pigeonpea. Increased dry matter production with the increased leaf area, number of branches, NPK uptake. In general, FYM enhances the adsorptive capacity for anionic and cationic nutrients. These ions release slowly to the soil for the whole crop growth period resulted in better availability of the nutrients during entire crop growth period (Singh, 2017). These findings were in line with the findings of Sharma *et al.* (2009) and Reddy *et al.* (2011).

Table 4 . Dry matter production (g plant^{-1}) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	30 DAS			60 DAS			90 DAS		
	19-20	20-21	Mean	19-20	20-21	Mean	19-20	20-21	Mean
Sequential intercropping systems (S)									
S_1 - Pigeonpea (180 cm)	2.09	2.42	2.26	11.33	15.03	13.18	64.67	70.00	67.33
S_2 - Paired row pigeonpea (60-300-60 cm)	2.03	2.44	2.23	10.67	14.20	12.43	62.83	67.45	65.14
S_3 - Pigeonpea + Sweetcorn – Chickpea	1.75	2.01	1.88	9.50	11.10	10.30	53.67	58.80	56.23
S_4 - Pigeonpea + Sweetcorn – Safflower	1.72	2.02	1.87	9.25	10.40	9.82	54.67	59.90	57.28
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	1.49	1.78	1.63	7.25	9.27	8.26	44.67	49.77	47.22
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	1.44	1.75	1.59	7.12	9.35	8.23	43.33	48.09	45.71
S.Em±	0.07	0.08	-	0.36	0.49	-	2.31	2.20	-
CD (p=0.05)	0.22	0.22	-	1.06	1.45	-	6.77	6.44	-
Integrated nutrient management (N)									
N_1 - 100 % RDN	1.67	1.97	1.82	8.56	10.75	9.65	48.83	54.31	51.57
N_2 - 75 % RDN + 25 % N through FYM	1.84	2.17	2.00	9.82	12.36	11.09	59.11	63.69	61.40
S.Em±	0.04	0.04	-	0.21	0.29	-	1.33	1.27	-
CD (p=0.05)	0.12	0.13	-	0.61	0.84	-	3.91	3.72	-
Interactions (SxN)									
S.Em±	0.10	0.11	-	0.51	0.70	-	3.27	3.10	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	1.75	2.07	1.91	9.19	11.55	10.37	53.97	59.00	56.48
CV (%)	10.26	9.05	-	9.63	10.47	-	10.48	9.11	-

RDN - Recommended dose of nitrogen through fertilizers; FYM-Farm yard manure

Table 4 (cont.). Dry matter production (g plant^{-1}) of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	120 DAS			At harvest		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sequential intercropping systems (S)						
S_1 - Pigeonpea (180 cm)	107.87	115.74	111.80	150.20	167.09	158.64
S_2 - Paired row pigeonpea (60-300-60 cm)	99.93	111.12	105.52	142.93	158.52	150.72
S_3 - Pigeonpea + Sweetcorn – Chickpea	87.90	95.45	91.68	129.23	140.92	135.08
S_4 - Pigeonpea + Sweetcorn – Safflower	83.25	91.30	87.27	124.09	136.51	130.30
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	73.57	79.56	76.56	110.40	123.74	117.07
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	72.21	79.40	75.81	108.73	118.62	113.68
S.Em±	3.30	3.32	-	3.89	4.62	
CD(p=0.05)	9.69	9.73	-	11.41	13.54	
Integrated nutrient management (N)						
N_1 - 100 % RDN	82.94	90.06	86.50	123.39	136.44	129.91
N_2 - 75 % RDN + 25 % N through FYM	91.97	100.79	96.38	132.19	145.36	138.77
S.Em±	1.91	1.91	-	2.25	2.67	

RDN - Recommended dose of nitrogen through fertilizers; FYM - Farm yard manure

Number of branches plant^{-1}

The average number of branches plant^{-1} increased linearly up to 120 DAS (19.05 and 20.87 during 2019-20 and 2020-21, respectively) and subsequently it increased with crop age but at decreasing rate. The number of branches plant^{-1}of pigeonpea crop was influenced by integrated nutrient management in different sequential intercropping systems at 30, 60, 90, 120 DAS and at harvest during both the years of study (Table 5). At all the growth stages, number of branches plant^{-1} of pigeonpea crop was significantly influenced by the sequential inter cropping systems except at 30 DAS where it was non-significant. Maximum number of branches plant^{-1} was recorded in sole pigeonpea (S_1) and which was on par with paired row pigeonpea (S_2) over pigeonpea sown with sequential intercrops (S_3, S_4, S_5 and S_6) at all the growth stages during both the years of study.

Significantly maximum number of branches plant^{-1} was recorded at harvest in sole pigeonpea (S_1) (26.64 and 28.36) and which was on par with the paired row pigeonpea (S_2) (25.20 and 25.84) during 2019-20 and 2020-21, respectively. The minimum number of branches plant^{-1} was recorded in treatments with sequential intercropping in paired row pigeonpea with sweet corn - safflower (S_6) (19.51 and 19.92) which was on par with the sequential intercropping in paired row pigeonpea with sweet corn - chickpea (S_5) (19.75 and 20.30) during 2019-20 and 2020-21, respectively. From the data it was also observed that increased number of branches from 120 DAS to harvest is very less compared to the up to 120 DAS in all the treatments. From this it was concluded that when pigeonpea was inter cropped with sweet corn during initial 80-90 days of pigeonpea largely decreased the number of branches plant^{-1}. The higher number of branches plant^{-1} of sole pigeonpea (S_1 and S_2) than pigeonpea with sequential inter crops (S_3, S_4, S_5 and S_6) may be due to competition of sweet corn with the pigeonpea for the space and light that leads to the

Table 5 . Number of branches plant^{-1} of pigeonpea as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	30 DAS			60 DAS			90 DAS		
	19-20	20-21	Mean	19-20	20-21	Mean	19-20	20-21	Mean
Sequential intercropping systems (S)									
S_1 - Pigeonpea (180 cm)	3.22	3.37	3.30	7.39	8.43	7.91	15.39	16.56	15.97
S_2 - Paired row pigeonpea (60-300-60 cm)	3.28	3.18	3.23	7.03	8.08	7.55	15.11	16.20	15.66
S_3 - Pigeonpea + Sweetcorn – Chickpea	3.06	3.22	3.14	6.28	6.52	6.40	12.61	13.56	13.08
S_4 - Pigeonpea + Sweetcorn – Safflower	3.11	3.11	3.11	6.22	7.13	6.67	12.61	14.39	13.50
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	3.06	3.11	3.08	5.56	6.33	5.95	10.78	12.49	11.63
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	3.06	3.06	3.06	5.50	6.13	5.81	10.89	11.91	11.40
S.Em±	0.08	0.12	-	0.22	0.26	-	0.47	0.52	-
CD (p=0.05)	NS	NS	-	0.65	0.76	-	1.39	1.52	-
Integrated nutrient management (N)									
N_1 - 100 % RDN	3.09	3.11	3.10	5.72	6.36	6.04	12.28	13.39	12.83
N_2 - 75 % RDN + 25 % N through FYM	3.17	3.24	3.20	6.94	7.85	7.39	13.52	14.98	14.25
S.Em±	0.05	0.07	-	0.13	0.15	-	0.27	0.30	-
CD (p=0.05)	NS	NS	-	0.38	0.44	-	0.80	0.88	-
Interactions (SxN)									
S.Em±	0.12	0.17	-	0.31	0.37	-	0.67	0.73	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	3.13	3.17	3.15	6.33	7.10	6.71	12.90	14.18	13.54
CV (%)	6.53	9.06	-	8.62	8.95	-	8.98	8.94	-

RDN - Recommended dose of nitrogen through fertilizers; FYM-Farm yard manure

Table 5 (cont.). Number of branches plant^{-1}ofpigeonpea (90 DAS and at harvest)as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	120 DAS			At harvest		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sequential intercropping systems (S)						
S_1 - Pigeonpea (180 cm)	23.00	25.40	24.20	26.64	28.36	27.50
S_2 - Paired row pigeonpea (60-300-60 cm)	21.11	22.82	21.96	25.20	25.84	25.52
S_3 - Pigeonpea + Sweetcorn – Chickpea	18.67	20.54	19.60	22.35	23.44	22.90
S_4 - Pigeonpea + Sweetcorn – Safflower	18.44	19.84	19.14	21.81	22.58	22.20
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	16.56	18.64	17.60	19.75	20.30	20.02
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	16.50	18.02	17.26	19.51	19.92	19.72
S.Em±	0.56	0.76	-	0.62	0.74	-
CD (p=0.05)	1.63	2.22	-	1.83	2.17	-
Integrated nutrient management (N)						
N_1 - 100 % RDN	18.15	19.85	19.00	21.62	22.23	21.93
N_2 - 75 % RDN + 25 % N through FYM	19.94	21.90	20.92	23.46	24.58	24.02
S.Em±	0.32	0.44	-	0.36	0.43	-
CD (p=0.05)	0.94	1.28	-	1.05	1.25	-
Interactions (SxN)						
S.Em±	0.79	1.07	-	0.88	1.05	-
CD (p=0.05)	NS	NS	-	NS	NS	-
General Mean	19.05	20.87	19.96	22.54	23.41	22.98
CV (%)	7.16	8.86	-	6.77	7.74	-

RDN - Recommended dose of nitrogen through fertilizers; FYM-Farm yard manure

decreased the number of branches in inter cropping system of pigeonpea and sweet corn. The more space and light available to the pigeonpea when sown without inter crops (S_1 and S_2), that leads to the better spreading of branches and finally higher number of branches plant^{-1}.

Sequential intercropping in pigeonpea with sweet corn – chickpea (S_3) (22.35 and 23.44) and pigeonpea with sweet corn – safflower (S_4) (21.81 and 22.58) were recorded higher number of branches plant^{-1} than sequential intercropping in paired row pigeonpea with sweet corn – chickpea (S_5) (19.75 and 20.30) and paired row pigeonpea with sweet corn – safflower (S_6) (19.51 and 19.92) during 2019-20 and 2020-21, respectively. The higher number of branches plant^{-1} in S_3 and S_4 than S_5 and S_6 may be due to close space between a pair of pigeonpea rows in S_5 and S_6 than S_3 and S_4, and again competition for space with sweet corn. These results were in line with Chaudhary and Thakur (2005) and Pramila Rani and Reddy (2010).

Number of branches plant^{-1} of pigeonpea was shown statistically significant difference between nutrient management practices *i.e.*, 100 % RDN through fertilizers (N_1) and 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) at all the crop growth stages under study during both the years (2019-20 and 2020-21) except 30 DAS where it was not significant. The maximum number of branches plant^{-1} was recorded at harvest in treatments in which application of 75 % RDN through fertilizers + 25 % RDN through FYM (N_2) (23.46 and 24.58) over 100 % RDN through fertilizers (N_1) (21.62 and 22.23) during 2019-20 and 2020-21, respectively. Higher number of branches plant^{-1} in N_2

over N_1 may be due to less internode elongation, enhanced and efficient use of added nutrients through combine form of organic and inorganic nutrients and its continuous availability throughout the growth period may increase the plant growth and development which encourages the physiological activities of the plant (Singh, 2017). These findings were in line with Sharma *et al.* (2009), Reddy *et al.* (2011) and Kumawat *et al.* (2015).

Seed yield of pigeonpea

The average seed yield of pigeonpea were 954 and 1099 kg ha^{-1} during 2019-20 and 2020-21, respectively. Irrespective of the treatments, higher seed yield of pigeonpea was recorded in 2020-21 than 2019-20. It may be due to suitable weather condition (temperature, solar radiation and rainfall) and yield attributing characters during 2020-21 over 2019-20) (Table 6). Significantly maximum seed yield was recorded in sole pigeonpea (S_1) (1172 and 1365 kg ha^{-1}) and which was on par with the paired row pigeonpea (S_2) (1116 and 1250 kg ha^{-1}) during 2019-20 and 2020-21, respectively. The minimum seed yield was recorded in treatments with sequential intercropping in paired row pigeonpea with sweet corn -chickpea (S_5) (778 and 900 kg ha^{-1}) which was on par with the sequential intercropping in paired row pigeonpea with sweet corn – safflower (S_6) (770 and 877 kg ha^{-1}) during 2019-20 and 2020-21, respectively. Sequential intercropping in pigeonpea with sweet corn – chickpea (S_3) (972 and 1125 kg ha^{-1}) and pigeonpea with sweet corn - safflower (S_4) (919 and 1079 kg ha^{-1}) were recorded higher seed yield than sequential intercropping in paired row pigeonpea with sweet corn - chickpea (S_5) (778 and 900 kg ha^{-1}) and paired row pigeonpea with sweet corn – safflower (S_6) (770 and 877 kg ha^{-1}) during 2019-20 and 2020-21, respectively. Sole pigeonpea (S_1) recorded 52.19 and 55.61 percent higher seed yield than sequential intercropping system in paired row pigeonpea + sweet corn - safflower (S_6) during 2019-20 and 2020-21, respectively. The higher seed yield of sole pigeonpea (S_1 and S_2) than pigeonpea with sequential inter crops (S_3, S_4, S_5 and S_6) may be due to higher growth attributing characters and number of pods plant^{-1}. Higher yield of pigeonpea is resolute by both source and sink capacity to accumulate the photosynthates (Saritha *et al.*, 2012). Source capacity is largely decided by the leaf area for efficient utilization of incident solar radiation. Number of pods plant^{-1} decides the sink capacity of pigeonpea crop. Considering both attributes (leaf area and number of pods), the treatment in which these two attributes were higher corresponding similar trend of yields was recorded in that treatment. Similarly, higher sole cropping yield of sole pigeonpea over pigeonpea with intercropping systems was also reported by Srivastava *et al.* (2004) and Pramila Rani and Reddy (2010). Between two nutrient management practices, the maximum seed yield recorded in treatments in which application of 75 % RDN through fertilizers + 25 % N through FYM (N_2) (1002 and 1156 kg ha^{-1}) over 100 % RDN through fertilizers (N_1) (907 and 1043 kg ha^{-1}) during 2019-20 and 2020-21, respectively. It may be due to application of inorganic fertilizers with FYM might increase the nutrient ions in the soil solution which eventually increase the number of nodules, strong root system that enables the increased nitrogen fixation. This might cause the better plant growth and development leads to the enhanced photosynthesis process and movement of photo assimilates to the sinks which turns higher yield attributing characters and finally yield of pigeonpea (Singh, 2017). Similar findings were also observed by Sharma *et al.* (2009).

Pigeonpea equivalent yield

Among all cropping system assessment indices, it is an important index to assess the performance of crops in given situation. Yield (economical) and price of component crops (sweet corn, chickpea and safflower) used to convert into base crop yield (Pigeonpea equivalent yield). The average pigeonpea equivalent yield was 3078 and 3365 kg ha^{-1} during 2019-20 and 2020-21, respectively (Table 6).The maximum pigeonpea equivalent yield was recorded in treatments with sequential intercropping of paired row pigeonpea with sweet corn - chickpea (S_5) (4593 and 5069 kg ha^{-1}) which was on par with the sequential intercropping of paired row pigeonpea + sweet corn - safflower (S_6) (4267 and 4614 kg ha^{-1}) during 2019-20 and 2020-21, respectively. Minimum pigeonpea equivalent yield was recorded in paired row pigeonpea (S_2) (1116 and 1250 kg ha^{-1}) and which was on par with the sole pigeonpea (S_1) (1172 and 1365 kg ha^{-1}) during 2019-20 and 2020-21, respectively. The higher pigeonpea equivalent yield in S_5 and S_6 than S_1, S_2 may be due to better performance and yields of component crops (sweet corn, chickpea and safflower) in sequential intercropping systems.

Table 6. Seed yield of pigeonpea and pigeonpea equivalent yield (kg ha^{-1}) as influenced by sequential inter cropping systems and integrated nutrient management during 2019-20 and 2020-21

Treatments	Seed yield of pigeonpea (kg ha^{-1})			Pigeonpea equivalent yield (kg ha^{-1})		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sequential intercropping systems (S)						
S_1 - Pigeonpea (180 cm)	1172	1365	1268	1172	1365	1268
S_2 - Paired row pigeonpea (60-300-60 cm)	1116	1250	1183	1116	1250	1183
S_3 - Pigeonpea + Sweetcorn – Chickpea	972	1125	1048	3735	4083	3909
S_4 - Pigeonpea + Sweetcorn – Safflower	919	1079	999	3583	3812	3697
S_5 - Paired row pigeonpea + Sweetcorn – Chickpea	778	900	839	4593	5069	4831
S_6 - Paired row pigeonpea + Sweetcorn – Safflower	770	877	824	4268	4614	4441
S.Em±	42	39	-	139	141	-
CD (p=0.05)	123	113	-	408	415	-
Integrated nutrientmanagement(N)						
N_1 - 100 % RDN	907	1043	975	2913	3194	3054
N_2 - 75 % RDN + 25 % N through FYM	1002	1156	1079	3242	3537	3389
S.Em±	24	22	-	80	82	-
CD (p=0.05)	71	65	-	236	239	-
Interactions(SxN)						
S.Em±	59	55	-	197	200	-
CD (p=0.05)	NS	NS	-	NS	NS	-
General Mean	954	1099	1027	3078	3365	3221
CV (%)	11	9	-	11	10	-

RDN - Recommended dose of nitrogen through fertilizers; FYM-Farm yard manure

Kale *et al*. (2020) also conveyed that, higher pigeonpea equivalent yield in intercropping systems might be due to increased plant population pressure facilitated more nutrient and soil moisture uptakes per unit area, as well as better light interception, which may have increased leaf area and leaf mass, resulting in better photosynthate translocation, which may have contributed to plant development and ultimately increased equivalent yield. In present study also evident that paired row pigeonpea + sweet corn - chickpea (S_5) recorded 312 and 306 percent higher pigeonpea equivalent yield than paired row pigeonpea (S_2) during 2019-20 and 2020-21, respectively. Sequential intercropping in paired row pigeonpea with sweet corn – chickpea (S_5) (4593 and 5069 kg ha^{-1}) and paired row pigeonpea with sweet corn - safflower (S_6) (4267 and 4614 kg ha^{-1}) were recorded higher pigeonpea equivalent yield than sequential intercropping in pigeonpea + sweet corn – chickpea (S_3) (3735 and 4083 kg ha^{-1}) and pigeonpea + sweet corn – safflower (S_4) (3583 and 3812 kg ha^{-1}) during 2019-20 and 2020-21, respectively. This may be due to lower performance and yields of component crops in sequential intercropping systems (S_3 and S_4). These results were in line with the findings of Musokwa and Mafongoya (2021). Between nutrient management practices, maximum pigeonpea equivalent yield was recorded in treatments in which application of 75% RDN through fertilizers + 25 % N through FYM (N_2) (3242 and 3537 kg ha^{-1}) over 100% RDN through fertilizers

(N_1) (2913 and 3194 kg ha^{-1}) during 2019-20 and 2020-21, respectively. It may also be due to higher yields of crops under N_2 over N_1. Similar results were also observed with the Sharma and Guled (2012).

Finally it can be concluded that, growth parameters of pigeonpea *i.e.*, plant height, leaf area, dry matter production plant^{-1} and number of branches plant^{-1}were recorded higher when pigeonpea sown as sole (S_1 and S_2) rather than pigeonpea in sequential intercropping systems (S_3, S_4, S_5 and S_6). Similarly, seed yield of pigeonpea also recorded higher in sole pigeonpea (S_1 and S_2). However, when we compare the pigeonpea equivalent yield, it was recorded higher in paired row pigeonpea with sweet corn - chickpea (S_5). Similarly, application of 75 % RDN through fertilizers and 25 % through FYM (N_2) recorded higher growth parameters, seed yield of pigeonpea and pigeonpea equivalent yield over application of 100% RDN through fertilizers (N_1).

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Research Article
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GROWTH AND PRODUCTIVITY OF *RABI* GROUNDNUT AFTER THIRTEEN DOUBLE CROP CYCLES UNDER ORGANIC NUTRIENT MANAGEMENT

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ABSTRACT

A field experiment was carried out at College of Agriculture, Rajendranagar, Hyderabad during two consecutive *rabi* seasons of 2016-17 and 2017-18 to evaluate six different nutrient management practices in randomized block design with four replications. The experimental soil was non-saline, neutral in reaction with sandy loam texture. Prior to conduct of this experiment, the field was under a long term study which was conducted to know the effect of organic, inorganic and integrated nutrient management practices on maize-onion cropping system since *kharif*, 2003-04 to 2014-15. Results revealed that significantly higher plant height, dry matter production at vegetative, flowering and harvest stages along with higher pod (3053 kg ha^{-1}) and haulm yield (5228 kg ha^{-1}) was recorded with application of 50% N through farm yard manure + 50% N through chemical fertilizers. Application of 100% nitrogen through organics like farm yard manure, neem cake and vermicompost along with biofertilizers like rhizobium and PSB and application of 100% recommended NPK through chemical fertilizers also recorded comparable yield and drymatter. Significantly lower plant height (18.80 cm), dry matter production (6243 kg ha^{-1}) at harvest stage along with lower pod yield (2230 kg ha^{-1}) and haulm yield (4228 kg ha^{-1}) was recorded in the treatment which received 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB at vegetative (1000 kg ha^{-1}), flowering (2712 kg ha^{-1}) and harvest (6243 kg ha^{-1}) stages than the rest of the treatment. No significant differences in the harvest index of the crop were recorded among different nutrient management practices.

Groundnut (*Arachis hypogaea* L.) is one of the most important oil seed and cash crops of India and is also known as ''King of oilseeds''. India ranks first in the world in respect to area and second in production after China. However, the productivity of groundnut is quite low as compared to world average productivity. The low productivity in India is mainly due to poor soil fertility, deterioration of soil physical properties and imbalanced use of organic and inorganic fertilizers for plant nutrients. Though it is said to be a self-fertilizing crop, it is very exhaustive compared to other legumes as it removes large amount of macro and micro-nutrients from soil and meeting the crop requirement with single nutrient source is difficult. Judicious use of organic manures such as farm yard manure (FYM) and farm wastes along with chemical fertilizers improves soil physical, chemical and biological properties and improves groundnut productivity (Balaguravaiah *et al*., 2005). Integrated use of chemical fertilizers along with organic manures and biofertilizers sustain the crop productivity and improves the soil fertility (Chavan *et al.,* 2014). Keeping the above points in view, a study was conducted to examine the effect of different nutrient management practices on growth and yield of *rabi* groundnut after thirteen double crop cycles under maize-onion organic nutrient management.

MATERIAL AND METHODS

A field experiment was conducted at the College farm, College of Agriculture, Rajendranagar, Hyderabad during two consecutive *rabi* seasons of 2016 - 17 and 2017-18. The field was under a long term study to evaluate the effect of organic, inorganic and integrated nutrient management practices on productivity of maize-onion cropping system from *kharif*, 2003-04 to 2014-15 under the ageis of AICRP - Integrated Farming Systems, Rajendranagar. The plot was maintained undisturbed and fallow during 2015-16. The experimental soil is non-saline, neutral in reaction with 61.9% sand, 23.8% silt and 12.5% clay and the texture is sandy loam (Udic Ustochrept). The initial fertility status of the soil was medium in organic carbon (0.81%), low nitrogen (255.2 kg ha^{-1}) high in phosphorus (68.2 kg ha^{-1}) and potassium (489 kg ha^{-1}). Six treatments *viz.,*T1: 50% N through FYM + 50% N through chemical

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fertilizers, T2: 100% N basal through FYM + neem cake + vermicompost each on 1/3rd basis), T3: 2/3rd N basal through FYM + neem cake + 1/3rd N top dress through vermicompost, T4: 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB, T5: 100% N through FYM + neem cake + vermicompost each on 1/3rd basis) + Biofertilizers for N and PSB, T_6: 100% NPK through chemical fertilizers (30:50:50 kg NPK ha^{-1}) were tested in randomized bock design with four replications.

Kadiri 6 (K6) variety of groundnut was used during both the years and sowing was done by dibbling method. The recommended dose of fertilizer of groundnut was 30-50-50 kg N, P_2O_5 and K_2O ha^{-1}, respectively and urea, single super phosphate and muriate of potash were used as sources for nitrogen, phosphorus and potassium, respectively. The nutritional composition (N-P-K %) of organic manures was 1.23 - 0.84 - 1.13 and 1.41 - 0.65 - 1.21, vermicompost, 0.62 - 0.22 - 0.72, and 0.55 - 0.17 - 0.58, FYM, 3.2 - 0.58- 1.23 and 2.88 - 0.52 - 1.36, neem cake during 2016-17 and 2017-18 respectively. All the manures were applied two weeks prior to sowing of crop while in treatment T3, FYM and neem cake were applied basally and vermicompost was top dressed at 30 DAS. In the T4 treatment rock phosphate was mixed with FYM and applied to soil as basal. Seed inoculation with *Rhizobium* strains was done before sowing and rock phosphate was mixed thoroughly with PSB before their application. Gypsum @ 500 kg ha^{-1} was applied in the root zone of groundnut at 40 DAS through last inter cultivation. Five plants from net plot area were randomly selected and observations on growth parameters were recorded at vegetative, flowering and at harvest stages of the crop. Pods from net plot were dried to constant weight and expressed in kg ha^{-1}. After thorough sun drying, haulm from each net plot were weighed and expressed as haulm yield in kg ha^{-1}. Harvest index was computed as percentage of pod yield to total biological yield (Pod yield + Haulm yield).

The growth and yield data of groundnut was subjected to year wise and pooled analysis in RBD to get the effect of different fertilizer treatments at 5% level of significance in two consecutive years i.e. *rabi,* 2016-17 and 2017-18.

RESULTS AND DISCUSSION

The growth parameters of groundnut increased progressively with the advancement of the crop and reached maximum at harvest of the crop.

Plant Height

The maximum plant height was observed at different stages *viz.,* vegetative, flowering and harvest stages of crop growth during *rabi,* 2016-17 and 2017-18 under the treatment which received 50% nitrogen through FYM and 50% of nitrogen through chemical fertilizers (table 1). Pooled data revealed that significantly higher mean plant height at vegetative (11.94 cm), flowering (22.73 cm) and harvest (23.22 cm) stages was with combined application of chemical fertilisers and organic manures compared with organic manures or inorganic fertilizers alone applied treatments and it was on par with 100% nitrogen applied through organics like FYM, neem cake and vermicompost along with bio-fertilizers like *Rhizobium* and PSB and 100% recommended NPK applied through chemical fertilizers. Significantly lower plant height at vegetative (9.93 cm), flowering (17.78 cm) and harvest (18.80 cm) stages was recorded in the treatment which received 50% N through FYM + bio-fertilizers for N, Rock phosphate for P and PSB. Application of organic manure not only supplied macro and micro nutrients, *viz.* N, P, K, and S but also improved availability of nutrients thereby increased growth attributes of crops (Datta *et al.,* 2014). Similar results were also reported by Chaudhary *et al.* (2015).

Drymatter Production

Examination of the pooled data indicated that dry matter production at vegetative (1287 kg ha^{-1}), flowering (3383 kg ha^{-1}) and harvest stages (7943 kg ha^{-1}) was higher with the integrated application of 50% nitrogen through FYM and 50% of nitrogen through chemical fertilizers and was on par with the treatment wherein 100% nitrogen was applied through organics like FYM, neem cake and vermicompost along with bio-fertilizers like Rhizobium and PSB and with 100% recommended NPK applied through chemical fertilizers (table 2). Significantly lower dry matter production was recorded in the treatment which received 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB at vegetative (1000 kg ha^{-1}), flowering (2712 kg

Table 1. Plant height (cm) at different growth stages of *rabi* groundnut under different nutrient management practices

Treatments	Vegetative stage			Flowering stage			At Harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 : 50% N through FYM + 50% N through Chemical fertilizers	11.67	12.22	11.94a	22.26	23.20	22.73a	23.19	23.25	23.22a
T_2 : 100% N basal through FYM + Neem cake + Vermicompost each on 1/3rd basis)	10.62	11.19	10.91b	19.85	20.10	19.98b	20.05	21.13	20.59b
T_3 : 2/3rd N basal through FYM + Neem cake + 1/3rd N top dress through Vermicompost	9.96	10.41	10.19b	20.30	20.80	20.55b	21.15	22.80	21.98b
T_4 : 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB	9.83	10.09	9.96b	18.78	17.78	18.28c	19.03	18.58	18.80
T_5 : 100% N through FYM + Neem cake + Vermicompost each on 1/3rd basis) + Biofertilizers for N and PSB	11.48	12.03	11.75a	22.20	23.10	22.65a	22.15	23.10	22.63a
T_6 : 100% NPK through chemical fertilizers (30:50:50 kg NPK ha^{-1})	11.18	11.65	11.41a	22.10	22.47	22.29a	22.12	23.00	22.56a
Mean	10.79	11.27	11.03	20.92	21.24	21.08	21.28	21.98	21.63
SE ± for Treatments	0.43	0.51	0.33	0.87	1.12	0.71	0.86	1.08	0.69
SE ± for Years	-	-	0.19	-	-	0.41	-	-	0.40
SE ± for Years × Treatments	-	-	0.47	-	-	1.00	-	-	0.98
CD (P=0.05) for Treatments	1.28	1.53	0.96	2.62	3.37	2.04	2.60	3.25	1.99
CD (P=0.05) for Years	-	-	NS	-	-	NS	-	-	NS
CD (P=0.05) for Years × Treatments	-	-	NS	-	-	NS	-	-	NS
CV (%)	7.90	9.03	8.51	8.30	10.52	9.49	8.10	9.80	9.02

***Same letter with in columns indicates no significant difference among the treatments. ($P \leq 0.05$)**

Table 2 . Dry matter production (kg ha^{-1}) at different growth of *rabi* groundnut under different nutrient management practices

Treatments	Vegetative stage			Flowering stage			At Harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 : 50% N through FYM + 50% N through Chemical fertilizers	1262	1311	1287a	3292	3474	3383a	7759	8126	7943a
T_2 : 100% N basal through FYM + Neem cake + Vermicompost each on 1/3rd basis)	1035	1123	1079b	2875	2973	2924b	6704	6868	6786b
T_3 : 2/3rd N basal through FYM + Neem cake + 1/3rd N top dress through Vermi compost	956	1083	1020b	3001	3159	3080b	6935	7294	7115b
T_4 : 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB	998	1001	1000b	2693	2731	2712c	6164	6322	6243c
T_5 : 100% N through FYM + Neem cake + Vermicompost each on 1/3rd basis) + Biofertilizers for N and PSB	1229	1302	1266a	3277	3416	3347a	7650	8012	7831a
T_6 : 100% NPK through chemical fertilizers (30:50:50 kg NPK ha^{-1})	1181	1204	1193a	3083	3216	3150a	7414	7748	7581a
Mean	1110	1171	1141	3037	3162	3099	7104	7395	7250
SE ± for Treatments	64	72	48	134	159	104	361	411	274
SE ± for Years	-	-	28	-	-	60.1	-	-	158
SE ± for Years × Treatments	-	-	68	-	-	147	-	-	387
CD (P=0.05) for Treatments	191	215	138	404	480	301	1089	1240	791
CD (P=0.05) for Years	-	-	NS	-	-	NS	-	-	NS
CD (P=0.05) for Years × Treatments	-	-	NS	-	-	NS	-	-	NS
CV (%)	11.4	12.2	11.8	8.8	10.1	9.5	10.1	11.1	10.7

***Same letter with in columns indicates no significant difference among the treatments. ($P \leq 0.05$)**

ha^{-1}) and harvest (6243 kg ha^{-1}) stages than the rest of the treatment (Fig.1). The production of organic acids and growth promoting substances during decomposition of organic manures might have facilitated easy availability of nutrients. Adequate supply of nutrients in turn was utilized for the formation of protoplasm and resulted in higher cell division and cell elongation. Thus an increase in yield parameters might have been obtained on account of overall improvement in the vegetative growth of the plant due to the application organic manures in combination with inorganics. (Kulakarni *et al.*, 2018).

kg ha^{-1}) and with 100% nitrogen applied through organics like FYM, neem cake and vermicompost along with biofertilizers of rhizobium and PSB (2853 kg ha^{-1}). There was no difference in pod yield (2656 and 2719 kg) between the basal application of 100% N through FYM + neem cake + vermicompost each on 1/3rd basis and basal application of 2/3rd N through FYM + Neem cake and top dressing of 1/3rd N through Vermicompost. However application of 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB recorded the significantly lower pod yield than all other treatments (2230 kg ha^{-1}). Similarly, the haulm

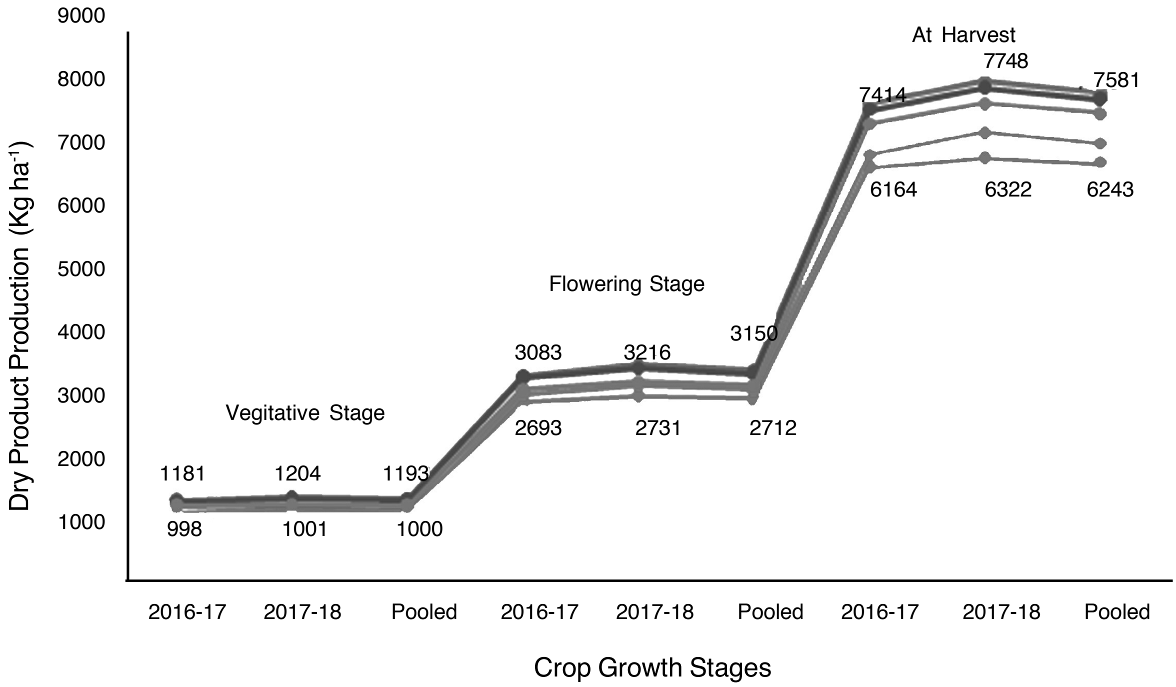

Fig.1 Dry matter production (kg ha^{-1}) at different growth stages of *rabi* groundnut under different nutrient management practices

Pod and Haulm Yield

The pod yield of groundnut was ranging from 2321 to 3026 kg ha^{-1} during *rabi,* 2016-17 and from 2139 to 3081 kg ha^{-1} during *rabi,* 2017-18 and significant differences were observed with different nutrient management practices (table 3). Pooled analysis of data revealed that the effect of years and the interaction between the years and treatments were nonsignificant. The mean pod yield pooled over years was significantly superior with the integrated application of 50% nitrogen through FYM and 50% of nitrogen through chemical fertilizers (3053 kg ha^{-1}) and was on par with the yield recorded with application of 100% recommended NPK through chemical fertilizers (2853

yield also recorded significantly higher in treatment received with the integrated application of 50% nitrogen through FYM and 50% of nitrogen through chemical fertilizers (5228 kg ha^{-1}) and lowest was with application of 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB recorded the significantly lower yield than all other treatments (4228 kg ha^{-1}). The combination of 50 per cent FYM + 50 per cent chemical fertilizers resulted in the highest pod yield and haulm yield which might be due to immediate release of nutrients through inorganic fertilizer and later by easy mineralization of manure resulting in steady supply of nutrients throughout the crop growth period (Salma *et al.*, 2018).

Table 3. Pod yield, haulm yield and harvest index of *rabi* groundnut under different nutrient management practices

Treatments	Pod Yield (kg ha^{-1})			Haulm Yield (kg ha^{-1})			Harvest Index (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 : 50% N through FYM + 50% N through Chemical fertilizers	3026	3081	3053a	5178	5277	5228aa	36.46	36.92	36.69a
T_2 : 100% N basal through FYM + Neem cake + Vermicompost each on 1/3rd basis)	2566	2745	2656b	4649	4799	4724b	34.88	36.42	35.65b
T_3 : 2/3rd N basal through FYM + Neem cake + 1/3rd N top dress through Vermicompost	2653	2784	2719b	4724	4949	4836b	34.98	36.05	35.52b
T_4 : 50% N through FYM + Bio-fertilizers for N, Rock phosphate for P and PSB	2321	2139	2230c	4153	4303	4228c	34.94	33.24	34.09a
T_5 : 100% N through FYM + Neem cake + Vermicompost each on 1/3rd basis) + Biofertilizers for N and PSB	2899	2927	2913a	5134	5334	5234a	35.27	35.34	35.31a
T_6 : 100% NPK through chemical fertilizers (30:50:50 kg NPK ha^{-1})	2793	2853	2823a	4950	5175	5063a	35.06	35.54	35.30a
Mean	2710	2755	2732	4798	4973	4886	35.27	35.59	35.43
SE ± for Treatments	148	155	107	223	226	159	1.97	1.49	1.23
SE ± for Years	-	-	61.8	-	-	91.6	-	-	0.71
SE ± for Years × Treatments	-	-	151	-	-	224	-	-	1.74
CD (P=0.05) for Treatments	445	467	309	672	681	458	NS	NS	NS
CD (P=0.05) for Years	-	-	NS	-	-	NS	-	-	NS
CD (P=0.05) for Years × Treatments	-	-	NS	-	-	NS	-	-	NS
CV (%)	10.9	11.2	11.6	9.3	9.1	9.2	11.16	8.36	9.85

*Same letter with in columns indicates no significant difference among the treatments. ($P \leq 0.05$)

Harvest Index

The harvest index ranged from 34.94 to 36.46 during 2016-17 and from 33.24 to 36.92 during 2017-18. From the pooled data of the harvest index over the years which ranged from 35.30 to 36.69 it was observed that there were no significant differences between the treatments or different nutrient management practices. These results are in conformity with the findings of Melese *et al*., 2017. The increase in the growth attributes and yield attributes might be because of application of organic manures. These organic manures might be the reason for additional supply of plant nutrients and increased availability of nutrients and improved physical and biological properties of soil. Application of organic manures along with bio-fertilizers, phosphate solubilizing bacteria (PSB) could also be attributed to the supply available nutrients directly to the plants and also had solubilizing effect on fixed form of nutrients in soil.

CONCLUSION

The results of present investigation showed that combined application of mineral fertilizers with organic manures *i.e* application of 50% nitrogen through FYM and 50% of nitrogen through chemical fertilizers resulted in higher growth and yield of groundnut and it was on par with the organic nutrient management *i.e.* one third recommended nitrogen each from farmyard manure, vermicompost and neem cake along with Rhizobium and PSB and 100 % inorganic treatment. Continuous application of organics over the years also resulted in good yields under organic nutrient management.

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Research Article
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BIOEFFICACY OF INSECTICIDES AGAINST LEAF WEBBER IN CAULIFLOWER

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ABSTRACT

Studies on the bioefficacy of various insecticides against cauliflower leaf webber, *Crocidolomia binotalis* (Zeller) were conducted at College farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*, 2018-19 and 2019-20. Insecticides belonging to different groups were selected. Two sprays of the test insecticides were given at 15 days interval during curd initiation stage. Insect counts one day before spray and 3, 5 and 7 days after each spray were recorded. Among the various insecticides tested, chlorantraniliprole proved to be effective in reducing the population of leaf webber after both sprays recording lowest mean larval population of 0.20 larvae/plant at 7 days after second spray during first season followed by spinosad (0.33 larvae/plant), emamectin benzoate (0.33 larvae/plant) and indoxacarb (0.47 larvae/plant) which were on par. During second season, lowest leaf webber population of 0.33 larvae/plant was recorded in chlorantraniliprole treated plot which was on par with spinosad (0.47 larvae/plant), emamectin benzoate (0.47 larvae/plant) and indoxacarb (0.67 larvae/plant). The per cent reduction in different treatments over control at 7 days after second spray revealed that chlorantraniliprole proved to be effective in reducing the population of leaf webber by recording highest overall mean per cent reduction of 84.14 followed by emamectin benzoate, spinosad and indoxacarb with 78.90, 78.46 and 71.22%, respectively.

Cauliflower (*Brassica oleraceae* L *var. botrytis*) is one of the most important winter vegetables. It is a native of Southern Europe in the mediterranean region and was introduced to India in 1822 from England (Swarup and Chatterjee, 1972). It contains adequate quantities of vitamins A, B and C and minerals like phosphorous, potassium, calcium, sodium, and iron. It is consumed as vegetable in curries, soups and pickles and is low in fat but rich in dietary fibre. Bihar, Uttar Pradesh, West Bengal, Orissa, Assam, Haryana, Rajasthan and Maharashtra are the major cauliflower growing states. In Telangana, the area under cauliflower is 2.20 thousand hectares with a production of 33.97 mt and average productivity of 15.43 mt ha^{-1} (https://www.indiastat.com).

The insect pests are of major concern as they cause serious economic damage to the crop. The insect pests such as diamond back moth (DBM) *Plutella xylostella* (Linnaeus), tobacco caterpillar *Spodoptera litura* (Fabricius), leaf webber *Crocidolomia binotalis* (Zeller), head borer *Hellula undalis* (Fabricius), aphid, *Brevicoryne brassicae* (Linnaeus), mustard aphid *Lipaphis erysimi* (Kaltenbach) etc. attack the crop during various growth stages. Among these, leaf webber *C. binotalis* incidence is noticed during vegetative and curd formation stage and may persist till harvest. Its incidence may become serious during the dry season. The cauliflower leaves are skeletonized by the larvae which remain on the under surface of leaves in webs. The developed larvae feed on them voraciously and severe infestation results in entire defoliation of the plant. They may also bore into main stem and prevent head formation thereby causing considerable yield loss to cruciferous crops like cauliflower, cabbage, radish and mustard.

Farmers resort to repeated sprayings with several insecticides to manage these insects. However, repeated use of conventional insecticides poses problems such as development of insecticide resistance, environmental pollution, destruction of natural enemies and high productivity cost. On the other hand, several new insecticides belonging to different groups are being developed and marketed in quick succession. Owing to their easy availability and quick action these insecticides are being readily used by the farming community. Since the exclusion of chemical insecticides is impractical especially when the insect load is high, the use of most selective and effective insecticides is

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essential to minimize the pest damage and maximize the benefits. Hence, the present investigation has been contemplated to evaluate the bio-efficacy of novel and conventional insecticides against leaf webber in cauliflower.

MATERIAL AND METHODS

A field trial was taken up during *rabi*, 2018-19 and 2019-20 at College Farm, College of Agriculture, Rajendranagar. Cauliflower seedlings were transplanted at 60 cm x 45 cm spacing in 5 m x 4 m plots on ridges and furrows. The experimental design was randomized complete block design (RBD) consisting of eight treatments in three replications. Insecticides belonging to different groups were selected for determining their bio-efficacy against insect pests in cauliflower. The details of the insecticides used and their dosages are given in table 1. In all the treatments, two sprayings were given during the course of investigation. First spraying was done at curd initiation stage when pest incidence was above ETL and second spraying was taken up 15 days after the first spray. The observations on insect pests were recorded one day before spraying as pre-treatment counts. Post treatment counts were recorded at 3, 5 and 7 days after each spraying. The per cent reduction in different treatments over control at 7 days after spray was calculated by modified Abbot's formula (Fleming and Retnakaran, 1985).

$$\text{Population reduction (\%)} = \left[1 - \left\{\frac{\text{Post} - \text{treatment population in treatment}}{\text{Pre} - \text{treatment population in treatment}}\right\} x \left\{\frac{\text{Pre} - \text{treatment population in control}}{\text{Post} - \text{treatment population in control}}\right\}\right] x100$$

Table 1. Details of insecticides used for the study

S.No	Technical name	Trade name	Formulation	Dose (g *a.i.* / ha.)	g (or) ml per litre of water	Group (IRAC) and mode of action	Firm Name
1	Chlorantraniliprole	Coragen	18.5% SC	10	0.1	28 Ryanodine receptor modulators	M/s FMC
2	Spinosad	Success	2.5% SC	17.5	1.4	5 Nicotinic acetylcholine receptor (nAChR) allosteric modulators	M/s Dow Agro Sciences
3	Emamectin benzoate	Proclaim	5% SG	10	0.4	6 Glutamate-gated chloride channel (GluCl) allosteric modulators	M/s Syngenta
4	Indoxacarb	King doxa	14.5% SC	40	0.55	22A Voltage-dependent sodium channel blockers	M/s Gharda Chemicals
5	Diafenthiuron	Pegasus	50% WP	300	1.2	12 Inhibitors of mitochondrial ATP synthase	M/s Syngenta
6	Chlorpyriphos	Lethal	50% EC	500	2.0	1 B (Organo phosphates)	M/s Insecticides India
7	Dimethoate	Tafgor	30% EC	200	1.3	1 B (Organo phosphates)	M/s Rallis

RESULTS AND DISCUSSION

Season I (2018-19)

The population of *C. binotalis* in various treatments a day before spraying ranged from 3.67 to 4.07 larvae/plant (Table 2). There was no significant difference in population among the various treatments. At 3, 5 and 7 days after spraying (DAS) all the insecticidal treatments were significantly superior over control. Chlorantraniliprole recorded significantly lowest leaf webber population and was on par with spinosad, emamectin benzoate and indoxacarb but was significantly different from chlorpyriphos, diafenthiuron and dimethoate which were found to be on par with each other. The per cent reduction of leaf webber in different treatments over control in decreasing order of efficacy was chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 86.90, 85.0, 81.0, 79.64, 52.50, 42.38 and 27.45 % reduction, respectively.

The pre count of leaf webber a day before second spray ranged from 1.53 to 4.47 larvae/plant. At 3, 5 and 7 DAS, chlorantraniliprole continued its supremacy over other treatments and was on par with emamectin benzoate, spinosad and indoxacarb. Chlorpyriphos was found to be next in order of effectiveness followed by diafenthiuron which were on par with each other. The per cent reduction in larval population over control was 87.74, 83.79, 81.92, 76.50, 58.09, 47.25 and 34.0 in chlorantraniliprole, emamectin benzoate, spinosad, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate, respectively.

Season II (2019-20)

The population of leaf webber in various treatments a day before spraying ranged from 5.87 to 6.27 larvae/plant. No significant difference was observed in population among the various treatments (Table 3). At 3 and 5 DAS, chlorantraniliprole recorded significantly lower leaf webber population and was on par with spinosad, emamectin benzoate and indoxacarb. At 7 DAS, similar trend was observed wherein chlorantraniliprole showed greater efficacy in reducing leaf webber population and was on par with spinosad and emamectin benzoate but significantly different from indoxacarb which was on par with the latter two insecticides. Other treatments *viz*., chlorpyriphos, diafenthiuron and dimethoate recorded higher population of leaf webber but all the insecticidal treatments were significantly superior over control. The per cent reduction of leaf webber in different treatments over control in decreasing order of efficacy was chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 82.77, 77.98, 77.06, 73.37, 51.00, 32.07 and 26.77, respectively.

The population of leaf webber one day before second spray ranged from 1.87 to 6.40 larvae/plant. At 3, 5 and 7 DAS, significantly lowest leaf webber population was recorded in chlorantraniliprole which was on par with emamectin benzoate, spinosad and indoxacarb but differed significantly from chlorpyriphos, diafenthiuron and dimethoate which were in turn on par with each other but significantly superior over control. The per cent reduction in larval population in various treatments over control in decreasing order of efficacy was chlorantraniliprole (80.36 %), emamectin benzoate (75.16 %), spinosad (73.45 %), indoxacarb (65.63 %), chlorpyriphos (49.07 %), diafenthiuron (44.23 %) and dimethoate (36.08 %).

Pooled efficacy (Season I and II)

A pooled analysis of the reduction of leaf webber population by various insecticides at 7 days after first and second spray over a period of two years *i.e rabi*, 2018-19 and 2019-20 is given in table 4. Chlorantraniliprole recorded highest per cent reduction and was statistically on par with spinosad, emamectin benzoate and indoxacarb. The per cent reduction over control after I and II spray in chlorantraniliprole was 84.46 and 83.33% while in spinosad, emamectin benzoate and indoxacarb it was 80.76 and 76.15; 74.42 and 79.38 and 75.24 and 67.21 %, respectively. In the remaining three insecticides it was less than 50% in either of the two sprays. The overall mean per cent reduction revealed that chlorantraniliprole was the most effective insecticide against leaf webber with reduction in population (84.14%) followed by emamectin benzoate (78.90%), spinosad (78.146%) and indoxacarb (71.22%). Chlorpyriphos, diafenthiuron and dimethoate were least effective with 51.48, 40.07 and 31.18 per cent reduction over control, respectively.

Thus, from the present studies it is clearly evident that chlorantraniliprole was the best treatment in managing leaf webber in cauliflower followed by

Table 2. Bioefficacy of insecticides against leaf webber in cauliflower during *rabi*, 2018-19

Insecticide	Dosage (g or ml)/l	Number of leaf webber larvae/plant*				Per cent reduction over control after I spray	Number of leaf webber larvae/plant*				Per cent reduction over control after II spray
		Pre-Spray	3 DAS I	5 DAS I	7 DAS I		Pre-Spray	3 DAS I	5 DAS I	7 DAS II	
Chlorantraniliprole 18.5 SC	0.1	3.87 (2.20)	0.73 [a] (1.31)	0.60 [a] (1.26)	0.53 [a] (1.23)	86.90	1.53 [a] (1.59)	0.33 [a] (1.15)	0.27 [a] (1.13)	0.20 [a] (1.10)	87.74
Spinosad 2.5 SC	1.4	3.80 (2.19)	0.80 [a] (1.34)	0.67 [a] (1.28)	0.60 [a] (1.26)	85.00	1.73 [a] (1.65)	0.47 [a] (1.21)	0.40 [a] (1.18)	0.33 [a] (1.15)	81.92
Emamectin Benzoate 5 SG	0.4	3.67 (2.16)	0.80 [a] (1.34)	0.73 [a] (1.32)	0.73 [a] (1.31)	81.00	1.93 [a] (1.71)	0.40 [a] (1.18)	0.33 [a] (1.15)	0.33 [a] (1.15)	83.79
Indoxacarb 14.5 SC	0.55	3.73 (2.18)	0.93 [a] (1.39)	0.87 [a] (1.36)	0.80 [a] (1.34)	79.64	1.87 [a] (1.69)	0.60 [a] (1.26)	0.53 [a] (1.23)	0.47 [a] (1.21)	76.50
Diafenthiuron 50 WP	1.2	4.07 (2.24)	2.73 [b] (1.92)	2.67 [b] (1.90)	2.47 [bc] (1.86)	42.38	2.73 [b] (1.93)	2.13 [bc] (1.77)	1.87 [bc] (1.69)	1.53 [b] (1.59)	47.25
Chlorpyriphos 50 EC	2.0	3.73 (2.17)	2.07 [b] (1.75)	2.00 [b] (1.73)	1.87 [b] (1.69)	52.50	2.40 [b] (1.84)	1.60 [b] (1.61)	1.40 [b] (1.55)	1.07 [b] (1.44)	58.09
Dimethoate 30 EC	1.3	3.67 (2.16)	3.00 [b] (1.99)	2.93 [b] (1.98)	2.80 [c] (1.95)	27.45	3.13 [b] (2.03)	2.53 [c] (1.87)	2.33 [c] (1.82)	2.20 [c] (1.79)	34.00
Control	-	4.07 (2.24)	4.13 [c] (2.27)	4.20 [c] (2.26)	4.27 [d] (2.29)	0.00	4.47 [c] (2.34)	4.87 [d] (2.42)	4.80 [d] (2.41)	4.73 [d] (2.39)	0.00
C.D.	-	N/S	0.25	0.24	0.19	-	0.24	0.18	0.19	0.18	-
SE(m)	-		0.082	0.08	0.06	-	0.08	0.06	0.06	0.06	-
SE(d)	-		0.12	0.11	0.09	-	0.11	0.08	0.07	0.08	-
C.V.	-		8.56	8.35	6.49	-	7.32	6.13	6.90	6.97	-

*Mean of 5 plants

Figures in parenthesis are square root transformed values;

DAS – Days after spraying; I – First spray; II – Second spray

Table 3. Bioefficacy of insecticides against leaf webber in cauliflower during *rabi*, 2019-20

Insecticide	Dosage (g or ml) /l	Number of leaf webber larvae/plant*				Per cent reduction over control after I spray	Number of leaf webber larvae/plant*				Per cent reduction over control after II spray
		Pre-Spray	3 DAS I	5 DAS I	7 DAS I		Pre-Spray	3 DAS I	5 DAS I	7 DAS II	
Chlorantraniliprole 18.5 SC	0.1	6.07 (2.66)	1.53^{a} (1.59)	1.33^{a} (1.52)	1.07^{a} (1.44)	82.77	1.87^{a} (1.69)	0.47^{a} (1.21)	0.40^{a} (1.18)	0.33^{a} (1.15)	80.36
Spinosad 2.5 SC	1.4	5.93 (2.63)	1.60^{a} (1.61)	1.40^{a} (1.55)	1.33^{ab} (1.53)	77.98	1.93^{a} (1.71)	0.60^{a} (1.26)	0.53^{a} (1.23)	0.47^{a} (1.21)	73.45
Emamectin Benzoate 5 SG	0.4	6.27 (2.70)	1.60^{a} (1.61)	1.47^{a} (1.57)	1.47^{ab} (1.57)	77.06	2.07^{a} (1.75)	0.53^{a} (1.23)	0.47^{a} (1.21)	0.47^{a} (1.21)	75.16
Indoxacarb 14.5 SC	0.55	6.13 (2.67)	1.87^{a} (1.69)	1.73^{a} (1.65)	1.67^{b} (1.63)	73.37	2.13^{a} (1.77)	0.80^{a} (1.34)	0.73^{a} (1.31)	0.67^{a} (1.29)	65.63
Diafenthiuron 50 WP	1.2	5.87 (2.62)	4.47^{b} (2.34)	4.33^{bc} (2.31)	4.07^{d} (2.25)	32.07	4.73^{bc} (2.39)	2.87^{c} (1.96)	2.60^{c} (1.90)	2.40^{c} (1.84)	44.23
Chlorpyriphos 50 EC	2.0	6.27 (2.69)	3.87^{b} (2.21)	3.33^{b} (2.08)	3.13^{c} (2.03)	51.00	3.60^{b} (2.14)	1.93^{b} (1.71)	1.80^{b} (1.67)	1.67^{b} (1.63)	49.07
Dimethoate 30 EC	1.3	6.07 (2.66)	4.80^{b} (2.41)	4.60^{c} (2.37)	4.53^{d} (2.35)	26.77	4.93^{c} (2.44)	3.27^{c} (2.06)	3.07^{c} (2.01)	2.87^{c} (1.97)	36.08
Control	-	6.20 (2.68)	6.33^{c} (2.71)	6.27^{d} (2.70)	6.20^{e} (2.71)	0.0	6.40^{d} (2.72)	6.33^{d} (2.71)	5.93^{d} (2.63)	5.80^{d} (2.61)	0.0
C.D.	-	N/S	0.21	0.21	0.14	-	0.22	0.20	0.20	0.16	-
SE(m)	-		0.07	0.07	0.05	-	0.07	0.06	0.07	0.05	-
SE(d)	-		0.10	0.10	0.06	-	0.10	0.09	0.09	0.07	-
C.V.	-		5.82	6.16	4.07	-	6.09	6.56	7.02	5.49	-

*Mean of 5 plants

Figures in parenthesis are square root transformed values;

DAS – Days after spraying; I – First spray; II – Second spray

Table 4. Bioefficacy of insecticides against leaf webber in cauliflower (Pooled Mean)

Treatments	Per cent reduction over control after I spray	Per cent reduction over control after II spray	Overall mean per cent reduction
Chlorantraniliprole 18.5 SC	84.46 [a] (66.79)	83.83 [a] (66.35)	84.14 [a](66.57)
Spinosad 2.5 SC	80.76 [a] (64.03)	76.15 [a] (61.43)	78.46 [a](62.54)
Emamectin Benzoate 5 SG	78.42 [a] (62.45)	79.38 [a] (63.06)	78.90 [a](62.64)
Indoxacarb 14.5 SC	75.24 [a] (60.32)	67.21 [a] (55.88)	71.22 [a](57.86)
Diafenthiuron 50 WP	35.51 [bc] (36.41)	44.62 [b] (41.86)	40.07 [bc](39.17)
Chlorpyriphos 50 EC	48.68 [b] (44.07)	54.27 [b] (47.45)	51.48 [b] (45.83)
Dimethoate 30 EC	26.82 [c] (30.63)	35.55 [b] (36.58)	31.18 [c](33.88)
Control	0.00[d](0.00)	0.00[c](0.00)	0.00 [d](0.00)
C.D.	9.67	12.28	6.69
SE(m)	3.16	4.01	2.18
SE(d)	4.47	5.67	3.09
C.V.	12.00	14.91	8.21

Figures in parentheses are angular transformed values

spinosad, emamectin benzoate and indoxacarb. All these four insecticides have a novel mode of action targeting insect ryanodine receptors, nicotinic acetylcholine receptors, GABA receptors and blocking sodium channels, respectively. Chlorantraniliprole belonging to the anthranilic diamide chemical class has a novel mode of action. It acts as an activator of insect ryanodine receptors causing rapid muscle dysfunction and paralysis. It is a broad spectrum foliar insecticide with contact and systemic action, widely used on vegetables in India for the management of lepidopteran insects both in field and poly houses. Bhede (2017) reported that cyantraniliprole, emamectin benzoate, chlorantraniliprole, flubendiamide and novaluron were found effective against leaf webber larvae providing 98.44, 95.40, 91.76, 90.11 and 85.22 per cent reduction in larval population followed by thiodicarb, chlorfenapyr, fipronil and diafenthiuron in cauliflower. Similarly in mustard, Kalasariya and Parmar (2020) evaluated insecticidal spray schedules against leaf webber *C. binotalis* and reported that schedule 3 consisting of thiamethoxam 25 WG @ 0.006% at seedling stage, emamectin benzoate 5 WG @ 0.0025% at pre-flowering stage, *Nomuraea rileyi* @ 2.5 kg/ha at 50% flowering stage and chlorpyriphos 16% + alphamethrin 1% EC @ 0.055% (S_3) at 50% pod formation stage were found superior in managing leaf webber. The literature on bioefficacy of newer insecticides on leaf webber in cauliflower is scanty. However, greater efficacy of novel insecticides on other lepidopteran pests like DBM, Spodoptera have been confirmed by several authors (Chowdary and Sharma, 2019; Harika *et al.,* 2019; Babu *et al.,* 2002; Liu *et al.,* 2003, Stanikzi and Thakur, 2016, Gaikwad *et al.,* 2018 Nayak *et al.*, 2019 and Mane *et al.,* 2020). Also, laboratory studies (Kannan *et al*., 2011) proved the effectiveness of the novel insecticides against leaf webber compared to conventional insecticides. Similar studies by Sambathkumar (2020) revealed that chlorantraniliprole 18.5% SC and flubendiamide 39.5% SC exposure for short period (24 hrs) led to feeding cessation and complete control of DBM and leaf webber.

CONCLUSION

Leaf webber is one the major pests with a potential to negatively impact the production of cole crops. Timely intervention helps in reducing insect pest population resulting in qualitative and quantitative increase in yields. Insecticidal sprays are inevitable and also provide quick control especially when the insect population is high. Novel insecticides like chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb can be successfully used in managing the pest. Also, these insecticides are required in less quantity and are safer to environment and specific to target pest. Thus, by spending towards plant protection, the damage can be minimized and greater income can be realized.

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APPLIED AND RESIDUAL PHOSPHORUS INFLUENCE ON CERTAIN GROWTH PARAMETERS AND YIELD OF *RABI* MAIZE SUCCEEDING *KHARIF* PIGEON PEA

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ABSTRACT

A field experiment was conducted at College farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during 2016-17 and 2017-18 to know the applied and residual phosphorus influence on certain growth parameters and yield of rabi maize succeeding *kharif* pigeonpea in split plot with residual treatments of redgram as main and phosphorus levels of maize as subplot treatments. At harvest, maize plant height (202.05 cm and 203.28 cm respectively) was significantly influenced by application of recommended dose of phosphorus (50 kg ha^{-1}) with 10% urea spraying as defoliant in kharif redgram in both the years under study over non application of defoliant (194.99 cm and 195.82 cm respectively). Leaf area index at 60 (4.93 and 5.21) and 90 days (4.45 and 4.57) also showed similar trend as plant height. In 2016-17 and 2017-18, the grain yield was highest in 75 kg P ha^{-1} + defoliant (7329 kg ha^{-1} and 7498 kg ha^{-1}) and it was at par with 50 kg P ha^{-1} + defoliant (6956 kg ha^{-1} and 7116 kg ha^{-1}) and these two treatments are significantly superior over others. The stover yield showed similar trend as grain yield.

Maize (*Zea mays* L.) is an important food and feed crop and is the world's widely grown highland cereal and primary staple food crop in many developing countries. It is the third most important cereal after rice and wheat as human food. Maize has high production potential compared to any other cereal crop. Hence, it is called as the "Miracle crop" and also "Queen of cereals" and because of its high yield potential and wider adaptability, it is finding a place in cropping systems.

Phosphorus play a pivotal role in photo-synthesis, root development, energy conservation and transformations, carbon metabolism, redox reactions, enzyme activation or inactivation, signalling and nucleic acid synthesis (Vance *et al.,* 2003). It also has a significant role in sustaining and build up soil fertility, particularly under intensive system of agriculture but it is one of the most inaccessible plant nutrients present in soil. Phosphorous is the backbone of balanced fertilization in Indian agriculture.The optimization of P levels of different sources while applying in combination assumes significance from the standpoint of economics of nutrient use. The phosphorus removal by first crop rarely exceeds 15-20% of added phosphorus and therefore its application to main crop will leave residual benefits for succeeding crop. Thus, assessment of residual phosphorus utilization by succeeding crop(s) in a cropping sequence is necessary for efficient use of phosphorus fertilizers. Soils face nutrients depletion due to aggressive cultivation of crops (Rehman *et al.*, 2018). Agrochemicals are key source of phosphorus which resides in soils flora longer period of time. It has been reported that over fertilization of phosphorus accumulates in soils and 75-90% of applied phosphorus fertilizer sources stay in the plough layer of soil and not taken up by crops (Cordell and White, 2014). Efficient application of P-fertilizers for better soil quality and crop yield is of utmost importance considering reduction in environmental perils.

The perenniality trait has been considered as undesirable in pigeonpea as it tends to limit pod set and reduce harvest index (Sheldrake and Narayanan 1979). Nevertheless, this trait could also be useful, as it ensures that not all the nitrogen fixed by the crop is partitioned into grain and a part is retained in vegetative structures, which could supply valuable nutrients to the following cereals if returned to soil. The defoliation and subsequent incorporation of these retained leaves at maturity may be necessary for maximizing residual benefit in adding organic matter to the soil to a

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subsequent cereal crop. The evolution of short duration varieties of pigeonpea have provided opportunity for multiple cropping in irrigated as well as rainfed area. The responses of the succeeding crops in a cropping system are influenced greatly by the preceding crops and the inputs applied therein. Intensive cropping systems are exhaustive feeders of plant nutrients and lead to depletion of soil fertility when a balanced and adequate replenishment of nutrients is continuously ignored where intensive cereal-cereal cropping systems. Therefore recently greater emphasis is being laid on the cropping system as whole rather than on the individual crops in a sequence.

MATERIAL AND METHODS

A field experiment to study the production potential of maize as influenced by applied as well as residual phosphorus and defoliant was conducted during *kharif* and *rabi* 2016-17 and 2017-18 at College Farm, College of Agriculture, Rajendranagar, Hyderabad, Southern Telangana. The soil of experimental site was sandy clay loam with pH of 7.6, Electrical conductivity 0.60 dSm^{-1}, low in organic carbon (0.53), low in available nitrogen (238.74 kg ha^{-1}) and medium in phosphorus (64 .06 kg ha^{-1}) and high in potassium (388.6 kg ha^{-1}). The experiment was laid out in a randomized block design during kharif 2016 and 2017 with seven treatments consisting of combinations of phosphorous levels and defoliant treatment with three replications for kharif pigeonpea (T_1 Control (0 NPK), T_2 RDF (20: 50: 0 N: P_2O_5: K_2O, T_3 20: 25: 0 N: P_2O_5: K_2O, T_4 20: 75: 0 N: P_2O_5: K_2O , T_5 20: 25: 0 N: P_2O_5: K_2O + Defoliant, T_6 20: 50: 0 N: P_2O_5: K_2O + Defoliant and T_7 20: 75: 0 N: P_2O_5: K_2O + Defoliant). The defoliant (urea) spray @ 10% at physiological maturity is done in pigeonpea crop. In succeeding rabi season, the experiment was laid out in Split-plot design by taking seven residual treatments from preceding pigeonpea crop as main plots and each at 50 (40 kg P ha^{-1}), 75 (60 kg P ha^{-1}) and 100 (80 kg P ha^{-1}) per cent recommended dose of phosphorus as three sub treatments with 3 replications for maize during rabi 2016-2017 and 2017-18. A uniform dose of nitrogen (240 kg N ha^{-1}) was applied in the form of urea (46% N) in three equal splits (1/3rd each at basal, at knee-high and tasseling). Similarly, the ½ of potassium (40 kg K_20 ha^{-1}) applied as basal dose remaining half (40 kg K_20 ha^{-1}) was applied along with urea during second top dressing at tasseling. The phosphorous was applied according to the treatments as basal dose.

RESULTS AND DISCUSSION

Plant Height (cm)

During both the years of study (2016-17 and 2017-18), the plant height at harvest was highest with application of 20: 75: 0+ Defoliant (T_7) (202.82 cm and 204.15 cm) followed by 20: 50: 0 + Defoliant (T_6) (202.05 cm and 203.28 cm) respectively and with significant disparity among rest of the treatments tested. Significantly lowest plant height was recorded with control (T_1) (169.77 cm and 170.76 cm) respectively. The improvement in plant height of maize with incorporation of legume crop residues might be due to the accumulation of high portion of nitrogen in the stover which was returned to the soil as residues might have contributed for the steady release of nitrogen to the succeeding crop. The superior performance of pigeonpea residues was due to the increase in biomass production coupled with increased uptake of nitrogen. The present findings are in corroboration with the reports of Tesfa *et al.* (2001), Radha Kumari and Srinivasulu Reddy (2009).

Among fertilizer levels, significant influence on plant height of maize at harvest was observed with the application of 100% RDP (S*ƒ*) (199.21 and 200.50) respectively during both the years of study.

Increasing level of phosphorus increased plant height at all the growth stages in both the years. This might be due to involvement of phosphorus in enhancing cell division and cell elongation which resulted and increase in stem elongation rate and ultimately plant height. These results are in agreement with the findings of Nimje and Seth (1988), Casas Cazares *et al.* (1991).

With regard to interaction between residual treatments and fertilizer levels was not observed during both years of study.

Dry Matter Production (g $plant^{-1}$)

During both years of study, the dry matter accumulation was significantly different with residual treatments of preceding pigeonpea crop on rabi maize from 30 days after sowing. The interaction between residual treatments in pigeonpea crop and succeeding fertilizer levels in maize dry matter production (g $plant^{-1}$) has exerted significant influence during both years from 60 days after sowing.

During both the years of study, the dry matter production recorded highest in 20: 75: 0+ Defoliant (T_7) (72.88 and 128.06 g plant^{-1} during 2016-17) and (72.89 and 129.81 g plant^{-1} during 2017-18). Significantly lowest dry matter was recorded with control (T_1) (38.98 and 88.01 g plant^{-1} during 2016-17) and (43.28, 88.95 and g plant^{-1} during 2017-18) at 60 and 90 days after sowing respectively. This was mainly due to increase in plant height and leaf area index. Phosphorus application favoured the uptake of nutrients which enhanced chlorophyll content and photosynthetic efficiency resulting higher dry matter accumulation. The results are in conformity with those of Jat *et al.* (2004) and Shivran and Ahlawat (2000a).

Fertilizer levels exerted a significant influence on dry matter production of maize and it was the highest with 100% RDP (Sƒ) (68.85 and 122.97 g plant^{-1} during 2016-17) and (68.67, 126.75 g plant^{-1} during 2017-18) at 60 and 90 days after sowing.

With regard to interaction between residual treatments and fertilizer levels, combination of T_7Sƒ (87.00 and 140 g plant^{-1} during 2016-17) and (86.00 and 143.08 g plant^{-1} during 2017-18) recorded the highest dry matter accumulation during both the years of study at 60, 90 days after sowing respectively. This could be ascribed to residual soil P by application of phosphorus to preceding crop. This might have modified and improved the overall nutritional environment of the soil conducive for the growth and development of maize crop. Corroborative findings were reported by Singh *et al.* (2011) and Shivran *et al.* (2000).

Incorporation of crop residue has resulted in significant improvement in dry matter accumulation since, legume residues have a narrow C: N ratio which was in the range of mineralization thus the mineralized N and the balance fertilization might have been equally available to the succeeding crop resulting in prolonged availability due to the reduced losses and fermentation of mineral complexes which was clearly evident in the residue incorporation treatments. Similar findings were also reported by Mckenzie *et al.* (2001).

Leaf Area Index (LAI)

During both the years of study, LAI was the highest in 20: 75: 0+ Defoliant (T_7) (4.93 and 4.53 during 2016-17) and (5.26 and 4.73 during 2017-18). Significantly lowest leaf area index was recorded with Control (T_1) (4.02 and 3.37 during 2016-17) and (4.29 and 3.52 during 2017-18) at 60 and 90 days after sowing respectively. The increase in LAI could be attributed to significant increase in leaf expansion, high rate of cell division and cell enlargement, rapid growth and there by improved quality of vegetative growth due to higher phosphorus application. The results of present investigation are in close conformity with findings of several researchers (Kumpawat and Rathore (1995) and Arya and Singh (2001).

Fertilizer levels exerted a significant influence on LAI of maize and it was the highest with 100% RDP (Sƒ) (4.84 and 4.33 during 2016-17) and (5.02 and 4.49 during 2017-18) at 60 and 90 days after sowing respectively during both the years of study.

With regard to interaction between residual treatments and fertilizer levels significant difference was not observed during both years of study.

Grain Yield (kg ha^{-1})

During both the years of study (2016-17 and 2017-18), the grain yield was the highest in 20: 75: 0 + Defoliant (T_7) (7329 kg ha^{-1}and 7498 kg ha^{-1} respectively) followed by 20: 50: 0 + Defoliant (T_6) (6956 kg ha^{-1} and 7116 kg ha^{-1} respectively) and with significant disparity between rest of the treatments tried to preceding pigeonpea. Significantly lowest grain yield was recorded with control (T_1) (4861 kg ha^{-1} and 5098 kg ha^{-1}) during the both years of study. Residue incorporation resulted in significant increase in grain yield of succeeding maize during both the years. The residue incorporation might have led to the increased solubulization of all the nutrients for absorption, which might have resulted in the enhanced yield attributes like number of grain per row, grain weight and test weight and finally in grain yield. The present findings are in corroboration with the results reported by Suryavanshi *et al.* (2008) and Dasaraddi *et al.* (2002).

During both the years of study, phosphorus levels exerted a significant influence on grain yield of maize and it was the highest with 100% RDP (Sƒ) (6715 kg ha^{-1} and 6995 kg ha^{-1} respectively) during both the years of study was observed in terms of grain yield. Marked increase in yield attributes of maize crop under increasing rates of phosphorus fertilization appears to be on account of vigorous in individual plant as reflected by increased height, LAI and total biomass accumulation. The results of present investigation are in close conformity with the findings of Arya and Singh (2001) and Kumar and Singh (2003).

With regard to interaction between residual treatments and fertilizer levels, combination of T_7S_3 (8730 kg ha^{-1} and 8932 kg ha^{-1} respectively) recorded the significantly higher grain yield with other treatments of present investigation, however which was on par with T_6S_3, (8059 kg ha^{-1} and 8224 kg ha^{-1} respectively) during both years of study. Higher yields in maize is mainly attributed to the residue incorporation might have provided positive impact on soil physical properties and fertility. This positive effect of soil fertility might have increased the availability of soil nitrogen. Residue incorporation may protect fertilizer losses, especially volatilization loss of N fertilizers thereby increasing uptake of N resulting in higher yields. The findings are in conformity with the experimental results of Egbe and Ali (2010) and Usman *et al.* (2013).

Stover Yield (kg ha^{-1})

During both the years of study (2016-17 and 2017-18), the stover yield was the highest in 20: 75: 0+ Defoliant (T_7) (10260 kg ha^{-1} and 10782 kg ha^{-1} respectively) followed by 20: 50: 0 + Defoliant (T_6) (10018 kg ha^{-1} and 10571 kg ha^{-1} respectively) during

Table 1. Plant height (cm) and Leaf area index of rabi maize as influenced by residual and applied phosphorus.

Main treatments	Plant Height (cm) at Harvest		Leaf Area Index 60 DAS		Leaf Area Index 90 DAS	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1 Control (0 NPK)	169.77	170.76	4.02	4.29	3.37	3.52
T_2 RDF (kg ha^{-1}) (20: 50: 0 N: P_2O_5: K_2O)	194.49	195.82	4.73	4.77	4.05	4.22
T_3 20: 25: 0	185.14	186.47	4.55	4.58	3.71	3.79
T_4 20: 75: 0	196.65	197.98	4.78	4.81	4.10	4.19
T_5 20: 25: 0+ Defoliant	186.26	187.59	4.58	4.61	3.75	3.89
T_6 20: 50: 0+ Defoliant	202.05	203.28	4.91	5.21	4.45	4.57
T_7 20: 75: 0+ Defoliant	202.82	204.15	4.93	5.26	4.53	4.73
S.Em±	1.73	1.59	0.04	0.05	0.07	0.09
CD (P=0.05)	5.32	4.90	0.12	0.15	0.20	0.27
Subplot treatments						
S_1 50% RDP	178.22	179.41	4.39	4.48	3.56	3.70
S_2 75% RDP	195.64	196.97	4.69	4.88	4.10	4.20
S_3 100% RDP	199.21	200.50	4.84	5.02	4.33	4.49
S.Em±	1.21	1.19	0.05	0.05	0.08	0.08
CD (P=0.05)	3.50	3.45	0.15	0.13	0.22	0.24
Interactions (TXS)						
S.Em±	3.13	3.02	0.12	0.11	0.18	0.20
CD (P=0.05)	NS	NS	NS	NS	NS	NS
S.Em±	3.20	3.15	0.14	0.12	0.20	0.22
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Dry matter production (g palnt^{-1}) of rabi maize at 60 DAS as influenced by residual and applied phosphorus.

Main treatments	2016				2017				MEAN			
	Sub plot treatments				Sub plot treatments				Sub plot treatments			
	Recommended Dose of phosphorus				Recommended Dose of phosphorus				Recommended Dose of phosphorus			
	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean
T_1 Control (0 NPK)	36.68	40.04	40.23	38.98	41.48	43.43	44.94	43.28	39.08	41.74	42.59	41.13
T_2 RDF (kg ha^{-1}) (20: 50: 0 N: P_2O_5: K_2O)	44.00	62.33	75.08	60.47	47.44	67.03	70.82	61.76	45.72	64.68	72.95	61.12
T_3 20: 25: 0	43.00	51.67	60.00	51.56	45.42	58.00	61.12	54.84	44.21	54.84	60.56	53.20
T_4 20: 75: 0	44.67	68.00	76.00	62.89	49.73	69.13	71.25	63.37	47.20	68.57	73.63	63.13
T_5 20: 25: 0+ Defoliant	43.98	55.00	61.00	53.33	46.17	58.11	65.42	56.57	45.08	56.56	63.21	54.95
T_6 20: 50: 0+ Defoliant	44.94	79.00	82.67	68.87	53.57	73.60	81.12	69.43	49.26	76.30	81.90	69.15
T_7 20: 75: 0+ Defoliant	49.31	82.33	87.00	72.88	56.12	76.56	86.00	72.89	52.72	79.45	86.50	72.89
MEAN	43.80	62.63	68.85		48.56	63.69	68.67		46.18	63.16	68.76	

	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Main treatments (M)	1.34	4.12	1.60	4.94
Sub plot treatments (S)	1.32	3.82	0.99	2.88
M at same level of S	3.15	9.22	2.68	7.94
S at same level of M	3.49	10.11	2.63	7.62

Table 3. Dry matter production (g palnt^{-1}) of rabi maize at 90 DAS as influenced by residual and applied phosphorus

Main treatments	2016				2017				MEAN			
	Sub plot treatments				Sub plot treatments				Sub plot treatments			
	Recommended Dose of phosphorus				Recommended Dose of phosphorus				Recommended Dose of phosphorus			
	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean
T_1 Control (0 NPK)	80.12	90.80	93.12	88.01	87.44	87.78	91.62	88.95	83.78	89.29	92.37	88.48
T_2 RDF (kg ha^{-1}) (20: 50: 0 N: P_2O_5: K_2O)	100.56	120.96	126.31	115.94	93.71	123.24	136.61	117.85	97.14	122.10	131.46	116.90
T_3 20: 25: 0	96.01	108.45	114.23	106.23	92.34	108.91	117.67	106.31	94.18	108.68	115.95	106.27
T_4 20: 75: 0	101.23	122.36	130.00	117.86	95.67	124.37	137.24	119.09	98.45	123.37	133.62	118.48
T_5 20: 25: 0+ Defoliant	93.02	112.56	118.85	108.14	96.45	112.20	119.99	109.54	94.74	112.38	119.42	108.84
T_6 20: 50: 0+ Defoliant	106.13	136.01	138.26	126.80	106.67	137.61	141.08	128.45	106.40	136.81	139.67	127.63
T_7 20: 75: 0+ Defoliant	107.23	136.96	140.00	128.06	107.00	139.36	143.08	129.81	107.12	138.16	141.54	128.94
MEAN	97.76	118.30	122.97		97.04	119.07	126.75		97.40	118.69	124.86	

	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Main treatments (M)	1.18	3.62	1.20	3.68
Sub plot treatments (S)	1.19	3.46	1.33	3.85
M at same level of S	2.84	8.30	3.11	9.10
S at same level of M	3.16	9.15	3.52	10.20

Table 4. Grain yield (kg ha^{-1}) of rabi maize as influenced by residual and applied phosphorus

Main treatments	2016				2017				MEAN			
	Sub plot treatments				Sub plot treatments				Sub plot treatments			
	Recommended Dose of phosphorus				Recommended Dose of phosphorus				Recommended Dose of phosphorus			
	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean
T_1 Control (0 NPK)	4659	4736	5187	4861	4937	5050	5306	5098	4798	4893	5247	4980
T_2 RDF (kg ha^{-1}) (20: 50: 0 N: P_2O_5: K_2O)	5261	5877	6869	6002	5382	6012	7361	6252	5322	5945	7115	6127
T_3 20: 25: 0	5218	5458	5593	5423	5338	5585	5722	5548	5278	5522	5658	5486
T_4 20: 75: 0	5351	6272	6955	6193	5474	6416	7449	6447	5413	6344	7202	6320
T_5 20: 25: 0+ Defoliant	5240	5500	5611	5451	5361	5661	5949	5657	5301	5581	5780	5554
T_6 20: 50: 0+ Defoliant	5386	7422	8059	6956	5510	7593	8244	7116	5448	7508	8152	7036
T_7 20: 75: 0+ Defoliant	5455	7803	8730	7329	5580	7983	8932	7498	5518	7893	8831	7414
MEAN	5224	6153	6715		5369	6329	6995		5297	6241	6855	

	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Main treatments(M)	176.90	545	155.01	478
Sub plot treatments(S)	105.52	306	90.32	262
M at same level of S	288.54	856	249.20	740
S at same level of M	279.19	809	238.97	692

Table 5. Stover yield (kg ha^{-1}) of rabi maize as influenced by residual and applied phosphorus

Main treatments	2016				2017				MEAN			
	Sub plot treatments				Sub plot treatments				Sub plot treatments			
	Recommended Dose of phosphorus				Recommended Dose of phosphorus				Recommended Dose of phosphorus			
	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean	50 %	75 %	100 %	Mean
T_1 Control (0 NPK)	7344	7925	7969	7746	7717	8328	8370	8139	7531	8127	8170	7943
T_2 RDF (kg ha^{-1}) (20: 50: 0 N: P_2O_5: K_2O)	8594	9304	9817	9238	9027	9687	10760	9825	8811	9496	10289	9532
T_3 20: 25: 0	7969	8873	8906	8583	8374	9329	9359	9021	8172	9101	9133	8802
T_4 20: 75: 0	8595	9375	10009	9326	9030	9852	10843	9908	8813	9614	10426	9617
T_5 20: 25: 0+ Defoliant	7991	8906	9089	8662	8538	9342	9674	9185	8265	9124	9382	8924
T_6 20: 50: 0+ Defoliant	8750	10000	11304	10018	9178	11042	11494	10571	8964	10521	11399	10295
T_7 20: 75: 0+ Defoliant	8750	10625	11406	10260	9195	11165	11986	10782	8973	10895	11696	10521
MEAN	8285	9287	9786		8723	9821	10355		8504	9554	10071	

	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Main treatments(M)	181.55	559	158.79	489
Sub plot treatments(S)	91.73	266	107.78	312
M at same level of S	268.76	801	281.82	833
S at same level of M	242.70	703	285.15	826

both the years of study and with significant disparity between rest of the treatments applied to preceding pigeonpea. Significantly lowest grain yield was recorded with control (T_1) (7746 kg ha^{-1} and 8139 kg ha^{-1} respectively) during the both years of study. Stover yield has also shown similar trend as that of grain yield. Residue incorporation has resulted in increase in stover yield. Higher biomass addition with symbiotic nitrogen fixation that might have helped in the accumulation of more biological yield which in turn reflected in enhancing the growth and yield was established by many researchers like Suryavanshi *et al*. (2008) and Dasaraddi *et al*. (2002).

During both the years of study, fertilizer levels exerted a significant influence on stover yield of maize and it was the highest with 100% RDP (S*ƒ*) (9786 kg ha^{-1} and 10355 kg ha^{-1} respectively) during both the years of study was observed in terms of stover yield. Increase in all the growth characters *viz.,* plant height, green leaves, LAI and dry matter accumulation resulted in an increase in stover yield during both the years. Arya and Singh (2001) and Kumar and Singh (2003) have also reported increase in stover yield with phosphorus application.

With regard to interaction between residual treatments and fertilizer levels, combination of T_7S*ƒ* (11406 and 11986 kg ha^{-1} respectively) recorded the significantly higher grain yield with other treatments of present investigation however which was on par with T_6S*ƒ* , (11304 and 11494 kg ha^{-1} respectively) during both the years of study.

CONCLUSION

Rabi maize (growth parameters like plant height, dry matter accumulation, leaf area index) raised as subsequent crop to *kharif* pigeonpea were significantly influenced by recommended dose of phosphorus (50 kg ha^{-1}) + defoliant applied to pigeonpea over no application of defoliant. The grain yield and stover yield of maize was maximum with 50 per cent higher dose of phosphorus + defoliant but at par with recommended dose of phosphorus + defoliant and these two treatments were significantly superior over others. Rabi maize fertilized with recommended dose of phosphorus (80 kg P ha^{-1}) significantly yielded higher grain and stover over 75 per cent and 50 per cent, indicating need of application recommended of phosphorus to *rabi* maize succeeding *kharif* pigeonpea.

Kharif pigeonpea fertilization with recommended phosphorus (50 kg ha^{-1}) + defoliant and 100% application of phosphorus (80 kg P ha^{-1}) to *rabi* maize are recommended for higher growth parameters, grain and stover yield.

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Research Article
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SEASONAL INCIDENCE OF MAJOR INSECT PESTS ON SUMMER SESAME IN RELATION TO ABIOTIC FACTORS

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ABSTRACT

A field experiment was conducted during summer, 2019 and 2020 to study the seasonal incidence of major insect pests and their correlation with weather parameters. The pooled results revealed that, the initial incidence of leaf webber and capsule borer, *A. catalaunalis* population and gall fly, *A. sesami* flower infestation was observed on 6th SMW and 10th SMW, respectively. The peak incidence of *A. catalaunalis* and *A. sesami* infestation noticed during on 13th SMW (0.82 larvae/plant) and 11th SMW (5.75 % flower infestation), respectively. After that population of *A. catalaunalis* was declined gradually and reached to zero per plant on 16th SMW. Regarding, the correlation with weather parameters, *A. catalaunalis* population shows a positive and non significant correlation with maximum temperature (0.020), minimum temperature (0.164) and nonsignificant negative correlation with morning relative humidity (-0.408), evening relative humidity (-0.089), sunshine hours (-0.167) and rain fall (-0.113). Flower infestation by *A. sesami* shows a positive and nonsignificant correlation with rainfall (0.106). The maximum temperature (-0.051), minimum temperature (-0.010), evening relative humidity (-0.148) and sunshine hours (-0.023) showed nonsignificant negative correlation and morning relative humidity (-0.745**) shows significant negative correlation. Multiple linear regression analysis revealed that, all weather parameters collectively influenced the *A. catalaunalis* population to the extent of 58.60 per cent and *A. sesami* infestation to the extent of 75.02 per cent on sesame.

Sesame, *Sesamum indicum* (L.) is the oldest oilseed crop of the world cultivated throughout India and considered as 'Queen of oilseeds' because of its superior oil quality. In India, it is grown in the entire crop growing season's *viz., kharif*, late *kharif*, *rabi* and summer seasons. Seeds of sesame contain 38-54 per cent oil content, 18-25 per cent protein, phosphorous, calcium and oxalic acid. It is grown in India with an area of 16.22 lakh ha, 6.57 lakh tonnes production and 405 kg ha^{-1} productivity. In Telangana sesame occupies an area of 21,000 ha with production and productivity of 0.14 lakh tonnes and 636 kg ha^{-1}, respectively (INDIASTAT, 2019-20).

Among several factors responsible for low yield of sesame, damage by insect pests is considered as one of the vital factor. This crop is attacked by 29 insect pests at different stages of its plant growth (Biswas *et al.,* 2001). Among insect pests, leaf webber and capsule borer (*A. catalaunalis)* is an important pest because it attacks the crop at all the growth stages starting from two weeks after emergence (Suliman *et al*., 2004). It feeds on tender foliage by webbing the top leaves, feed on flowers and bores into the pods. This insect pest causes 10-70 per cent infestation of leaves, 34-62 per cent of flower buds/ flowers and 10-44 per cent infestation of pods resulting in about 72 per cent loss in yield (Ahirwar *et al.,* 2010). Another serious pest of sesame is *A. sesami* Felt, commonly known as sesame gall fly and is widely distributed in South part of country. Maggots cause damage and feed inside the floral bud leading to formation of gall like structure and the damaged flower does not produce capsule. The affected buds wither and drop. As the sesame cultivation area increases in Telangana, it was exposed to varied environmental conditions. Information on the seasonal incidence of insect pests and its relation to weather parameters on sesame crop, particularly in this agro-climatic situation is scanty. Keeping these facts in view, present study on incidence of major insect pests was undertaken.

MATERIAL AND METHODS

The experiment was conducted for two consecutive summer seasons of 2019 and 2020 at

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Regional Agricultural Research Station, Polasa, Jagtial (18°15'15.8" N, 78°58'51.6" E) with swetha til variety. Sesame sowing was taken up in 500 m^2 plot during last week of January on 23.01.2019 and 21.01.2020 during respective years at a spacing of 30 X 15 cm and followed all agronomic practices for raising the sesame crop without any spraying of plant protection chemicals. The pest population was recorded in this unprotected plot of sesame at 7 days interval from the occurrence or initiation of the pest infestation and continued to maturity. A total of 10 plants from five random locations in the experimental plot were observed for incidence of leaf webber and capsule borer and gall fly. Data on leaf webber and capsule borer larval population was recorded and mean pest population per plant was computed. For gall fly, based on healthy and gall affected flowers the percent damage was calculated.

$$\text{Per cent flower infestation} = \frac{\text{Number of infested flowers}}{\text{Total number of flowers}} \times 100$$

In addition, weather data was recorded simultaneously from the meteorological observatory available at Regional Agricultural Research Station, Polasa, Jagtial and correlated with the occurrence of the insect pests of sesame. Among weather parameters, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall of preceding one week were considered for correlating with the occurrence of the insect pests of sesame. To work out the relationship between the occurrence of the insect pests of sesame and the weather parameters, correlation and multiple linear regressions (MLR) methods were adopted.

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{N\sum x^2 - (\sum x)^2 . N\sum y^2 - (\sum y)^2}}$$

Where,

r = Simple correlation coefficient

x = Independent variables, *i.e.* abiotic components

y = Dependent variables, *i.e.* pests

N = Number of observations

RESULTS AND DISCUSSION

During summer 2019, *A. catalaunalis* initial incidence was observed during 1st week of February (6th SMW) with mean larval population of 0.10 per plant larvae. While, pest population reached to peak by 3rd week of March (12th SMW) with mean population of 0.78 larvae per plant. Thereafter the pest population gradually declined and reached to 0.16 larvae per plant by 15th SMW (Table 1). Regarding *A. catalaunalis*

Table 1. Seasonal incidence of *A. catalaunalis* on sesame in relation to abiotic factors during summer 2019 and 2020

2019 & 2020	STD week	No. of leaf webber larvae/plant		
		Summer, 2019	Summer, 2020	Pooled (Summer,2019 & 2020)
29 Jan - 4 Feb	5	0.00	0.00	0.00
05 Feb - 11Feb	6	0.10	0.08	0.09
12 Feb - 18 Feb	7	0.24	0.04	0.14
19 Feb - 25 Feb	8	0.36	0.32	0.34
26 Feb - 4 Mar	9	0.48	0.52	0.50
05 Mar - 11 Mar	10	0.58	0.68	0.63
12 Mar - 18 Mar	11	0.64	0.42	0.53
19 Mar - 25 Mar	12	0.78	0.68	0.73
26 Mar - 01 Apr	13	0.68	0.92	0.82
02 Apr - 08 Apr	14	0.32	0.40	0.36
09 Apr - 15 Apr	15	0.16	0.18	0.17
16 Apr - 22 Apr	16	0.00	0.00	0.00

incidence during summer 2020, the initial incidence was observed on 6th SMW (1st week of February) with a mean population of 0.08 larvae per plant and the pest population reached to peak by 13th SMW (last week of March) with mean population of 0.92 larvae per plant. There after the pest population has declined gradually and reached to 0.18 larvae per plant on 15th SMW (9th to 15th April). The pooled data (figure1)

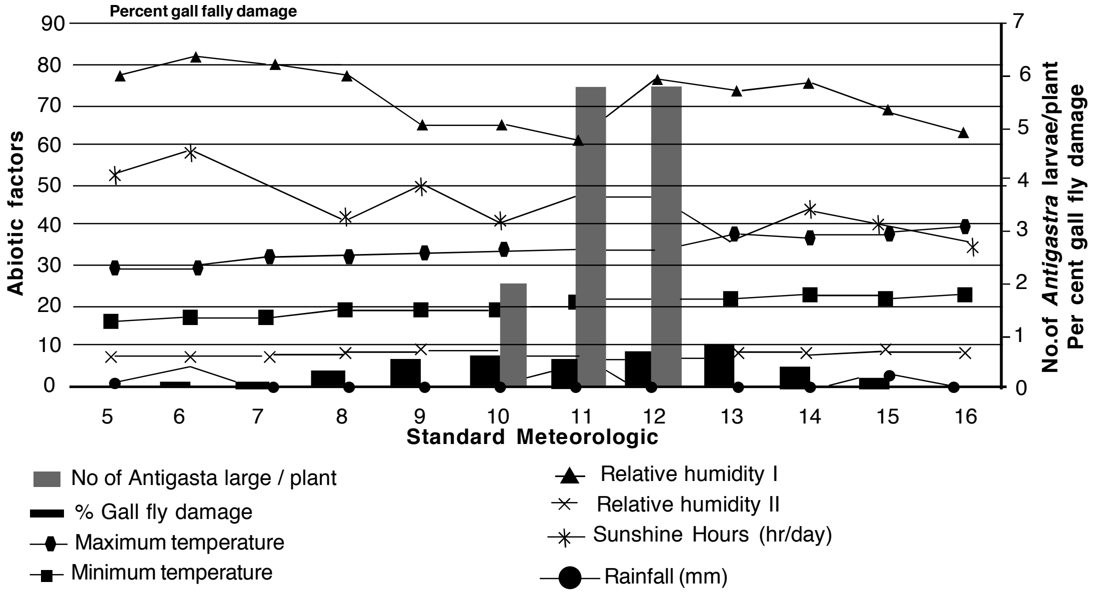

Fig 1. Pooled seasonal incidence of major insect pests on sesame in relation to abiotic factors during summer 2019 & 2020

pertaining to incidence of *A. catalaunalis* revealed that, larvae population commenced from 6th SMW (2nd week of February) with 0.09 larvae per plant and reached its peak (0.82 larvae per plant) during 2nd week of April (13th SMW). There after the pest population has declined gradually and reached to 0.17 larvae per plant by 2nd week of April (15th SMW). It indicates, the peak population of *A. catalaunalis* population was observed by nine weeks after sowing of sesame crop during summer season. These results were in line with Vishnupriya *et al.* (2003) who reported that the peak incidence of *A. catalaunalis* was observed on 1st fortnight of April after that population declines gradually. The present findings were in concurrence with Ramoliya Amith (2014) who reported that, the peak activity of *A. catalaunalis* was observed on 8th week after sowing of sesame crop.

The correlation studies on the seasonal incidence of *A. catalaunalis* with the preceding one week weather parameters (one week lag) during *summer* 2019 revealed that, maximum temperature (0.049), minimum temperature (0.197) and sunshine hours (0.082) showed positive and nonsignificant correlation. Whereas, morning relative humidity (-0.512), evening relative humidity (-0.332) and rainfall (-0.454) were negatively correlated with *A. catalaunalis* population but were nonsignificant. During *summer* 2020, maximum temperature (0.042), minimum temperature (0.002) and evening relative humidity (0.233) showed positive nonsignificant correlation. Whereas the morning relative humidity (-0.124), sunshine hours (-0.147) and rainfall (-0.194) showed negative and nonsignificant correlation with *A. catalaunalis* population. The pooled data of *A. catalaunalis* larval population with preceding one week weather parameters (one week lag), a positive and non significant correlation with maximum temperature (0.020), minimum temperature (0.164) and non significant negative correlation with morning relative humidity (-0.408), evening relative humidity (-0.089), sunshine hours (-0.167) and rainfall (-0.113) (Table 3).

Regression analysis of pooled data of *A. catlaunalis* larval population revealed that, all the weather parameters collectively influenced the *A. catalaunalis* larval population to the extent of 58.60 per cent (R^2 =0.586) on sesame. Multiple regression equation indicated that increase in one unit of minimum temperature and sunshine hours resulted in the corresponding increase of *A. catalaunalis* population by 0.272 and 0.052 units, respectively. Further, with one unit increase in, maximum temperature, evening relative humidity and rainfall the *A. catalaunalis* population decreased by 0.227, 0.022, 0.043 and 0.062, respectively.

The results of the present study were in agreement with Rakesh yalwar (2020) who reported nonsignificant and negative correlation with rain fall and these results are also in conformity with Kumar and Goel (1994) who reported that *A. catalaunalis* population was negatively correlated with evening relative humidity. Bharodia *et al.* (2005) reported positive correlation with maximum temperature, negative correlation with morning and evening relative humidity and rain fall. In concurrence with present findings, Kumar *et al.* (2009) reported that, weather parameters *viz.,* maximum and minimum temperatures showed nonsignificant positive correlation with *A. catalaunalis* larval population and nonsignificant negative correlation with relative humidity.

Y = 4.024-0.227 T max.+ 0.272Tmin.-0.022 RHI-0.043RHII+0.052SSH – 0.062RF

(R^2 = 0.59)

During summer 2019, the gall fly on sesame was noticed from 2nd week of March (10th SMW) with 2.04 per cent flower infestation (Table 2) while peak infestation was recorded during 3rd week of March (11th SMW) with 5.32 per cent flowers. The infestation decreased (3.70 per cent) by 4th week of March (12th SMW). Similar trend was noticed with regard to *A. sesami* infestation on sesame during summer 2020. The infestation of gall fly was observed on sesame during flowering stage of the crop and initial infestation (1.12 per cent) was observed during 2nd week of March (10th SMW). The peak infestation was observed on 3rd week of March (11th SMW) with infestation of 6.17 per cent and then infestation declined with minimum of 2.96 per cent on 4th week of March (12th SMW). The pooled data on flower infestation by *A. sesame* shows that the initial flower infestation was noticed by 2nd week of March (10th SMW) with 1.98 per cent flower infestation, coinciding with flowering. The peak flower infestation with a mean of 5.75 per cent was observed on 3rd week March (11th SMW). After that infestation decreased gradually with minimum infestation of 3.33 per cent on 4th week of March (12th SMW). The same findings were observed by Kumar *et al.* (2010) who reported that, sesame gall fly was found to be active from flowering to capsule formation stage.

The correlation studies between (Table 4) the incidence of *A. sesami* infestation with the preceding one week weather parameters (one week lag) during *summer* 2019 revealed that, maximum temperature (0.045) and sun shine hours (0.370) had nonsignificant positive correlation while minimum temperature (-0.001), evening relative humidity (-0.282), rainfall (-0.178) had nonsignificant negative correlation. However, the morning relative humidity showed (-0.757**) significant negative correlation. However, the morning relative humidity showed (-0.757**) significant correlation. The correlation studies between the seasonal incidence of *A. sesami* infestation with the preceding one week weather parameters (one week lag) during Summer, 2020 on sesame crop revealed that, minimum temperature (0.351), evening relative humidity (0.391) and rain fall (0.484) had nonsignificant positive correlation, respectively. The weather parameters, maximum temperature (-0.031) and morning relative humidity (-0.482) showed nonsignificant negative correlation and sunshine hours (-0.789**) showed significant negative correlation with *A. sesami* flower infestation. The pooled correlation on flower infestation with preceding one week weather parameters (one week lag), a positive and nonsignificant correlation with rainfall (0.106). The maximum temperature (-0.051), minimum temperature (-0.010), evening relative humidity (-0.148) and sunshine hours (-0.023) showed nonsignificant negative correlation with *A. sesami* infestation. The morning relative humidity (-0.745**) showed significant negative correlation.

These results were in supported by Ahuja and Kalyan (2001) who reported, gall fly infestation negatively correlated with temperature. It was also in accordance with Ahirwar and Banerjee (2009) who stated that, gall fly infestation negatively correlated with minimum temperature and relative humidity and positively correlated with rain fall.

Multiple step down regression analysis of pooled data revealed that, all the weather parameters except rain fall influenced the *A. sesami* infestation to an extent of 75.02 per cent (R^2 =0.75) on sesame. Multiple regression equation developed for *A. sesami* infestation with preceding one week weather parameters (one week lag) indicated that, increase in

Table 2. Seasonal incidence of *A. sesame* on sesame in relation to abiotic factors during summer 2019 and 2020

2019 & 2020	STD week	Per cent flower infestation of gall fly		
		Summer, 2019	Summer, 2020	Pooled (Summer, 2019 & 2020)
29 Jan - 04 Feb	5	0.00	0.00	0.00
05 Feb - 11Feb	6	0.00	0.00	0.00
12 Feb - 18 Feb	7	0.00	0.00	0.00
19 Feb - 25 Feb	8	0.00	0.00	0.00
26 Feb - 04 Mar	9	0.00	0.00	0.00
05 Feb - 11 Mar	10	2.04	1.92	1.98
12 Feb - 18 Mar	11	5.32	6.17	5.75
19 Feb - 25 Mar	12	3.70	2.96	3.33
26 Mar - 01 Apr	13	0.00	0.00	0.00
02 Apr - 08 Apr	14	0.00	0.00	0.00
09 Apr - 15 Apr	15	0.00	0.00	0.00
16 Apr- 22 Apr	16	0.00	0.00	0.00

Table 3. Correlation coefficients between *A. catalaunalis* larval population and weather parameters (one week lag) in sesame during summer 2019 and 2020

Weather parameters	Per cent flower infestation of gall fly		
	Summer, 2019	Summer, 2020	Pooled (Summer, 2019 & 2020)
Maximum temperature	0.049	0.042	0.020
Minimum temperature	0.197	0.002	0.164
Moring relative humidity (RH I)	-0.152	-0.124	-0.408
Evening relative humidity (RH II)	-0.332	-0.233	-0.089
Sunshine hours	0.082	-0.147	-0.167
Rain fall	-0.454	-0.194	-0.113

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

Table 4. Correlation coefficients between gall fly *A. sesami* infestation and weather parameters (one week lag) in sesame during summer 2019 and summer 2020

Weather parameters	Per cent flower infestation of gall fly		
	Summer, 2019	Summer, 2020	Pooled (Summer, 2019 & 2020)
Maximum temperature	0.045	-0.031	-0.051
Minimum temperature	-0.001	-0.351	-0.010
Moring relative humidity (RH I)	-0.757 **	-0.482	-0.745 **
Evening relative humidity (RH II)	-0.282	0.391	-0.148
Sunshine hours	0.370	-0.789 **	-0.023
Rain fall	0.178	0.484	0.106

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

one unit of minimum temperature resulted in the increase of *A. sesami* infestation by 0.41 units. Further, with one unit increase in maximum temperature, morning relative humidity, evening relative humidity and sunshine hours the *A. sesami* infestation decreased by 0.77, 0.23, 0.16 and 0.18 units, respectively in sesame.

Y = 45.373 - 0.762T max. + 0.390 T min. - 0.228RHI - 0.171RHII - 0.191SSH

($R^2 = 0.75$)

CONCLUSION

The *A. catalaunalis* incidence on sesame crop started from fifteen days after sowing and the peak incidence was noticed during last week of March (9th SMW) in *summer* sesame. The population decreased with crop maturity and weather parameters, temperature showed positive influence, while relative humidity and rainfall had negative influence on leaf webber and capsule borer incidence. Regarding *A. sesami,* the infestation was observed during flowering period of crop and maximum temperature, minimum temperature, evening relative humidity and sunshine hours had negative influence. However, morning relative humidity showed significant negative influence. Studies on the seasonal incidence of these insect pests hold a promising opportunity for the development of management tactics relevant to the control of these insect pests. Therefore, a detailed investigation on the impact of weather conditions in relation to pest incidence in the ecosystem assumes practical importance.

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Research Article
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MAPPING MAIZE VALUE CHAINS IN TELANGANA

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ABSTRACT

Value chains have always been in existence in agriculture in the sense that farms carried out production and the final consumer accessed the produce, with the produce being passed through several intermediaries. Maize which is regarded as the "Queen of Cereals" and second most important cereal crop across the world can be seen with consumption base in three important categories *i.e.,* feed, food and industrial. With the diversified end uses, maize industry in India is being dominated by many players *viz.*, farmers, aggregators/traders, processors (Feed industry/Starch industry) and consumers (Poultry industry/Food or feed industry. With existence of several small farms posing challenges in terms of highly dispersed collection of produce, transport arrangements, and quality assurance mechanisms, mapping the channels through which maize gets routed has been considered as an important means to know the deficiencies and thereby propose corrective measures. With this background, the present investigation was conducted to know the channels through which maize was routed amongst various value chain partners in maize in four districts of Telangana.

Maize has traditionally been grown as a staple food crop primarily for domestic consumption. However, in recent years, its demand has increased manifold because of its other diversiûed end-uses such as poultry and cattle feed, high quality starch and a wide array of industrial derivatives and different variants of food items such as sweet corn, popcorn, baby corn and other corn-based fast-food items. A value chain is a collection of activities that are performed by a company to create value for its customers (Porter, 1985). It refers to "the full range of activities which are required to bring a product or service from conception, through the intermediary phases of production, delivery to final consumers, and disposal after use" (Kaplinsky and Morris, 2002). A value chain can be a vertical linking or a network between various independent business organisations and can involve processing, packaging, storage, transportation and distribution (FAO, 2005).

Maize value chains in India are often fragmented, owing to the existence of many middlemen. Lack of information about other links in the chain had led to the inefficacies in the performance and thereby lower incomes especially to the maize growers. Also with the diversified consumption base, many players dominate in the chain, who obtain their inputs from one source and sell the final product to yet another source across the country. With the large number of small holdings, procurement of the produce is much diversified and tracing the route through which maize moves and analysing value added or service added becomes quite challenging. Under these circumstances, an understanding of the channels through which maize is procured and distributed shall help in knowing the lacunae with respect to each value chain partner that may further aid strengthening the entire value chain system as a whole. With this background, the current investigation was carried out taking four major districts under maize cultivation in Telangana.

MATERIAL AND METHODS

Exploratory research design was followed in the current investigation. Four districts of Telangana *viz.*, Kamareddy, Nizamabad, Karimnagar and Jagtial were considered. Two mandals from each of these districts and two villages from each mandal were selected. Ten maize growers from each village were interviewed, thus constituting a sample of 160 maize growers. Since a value chain encompasses various chain actors who have some stake in maize business, a sample of 80 stakeholders including, managers of various agencies involved in procurement, handling, storage, logistics and distribution such as MARKFED, PACS, DCMS, SWC's were interviewed besides the major end users of maize *viz.*, poultry farmers, processors, industry firms

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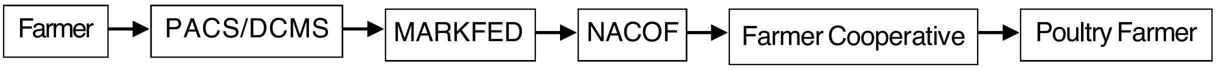
and few traders. For the present study with an objective of mapping existing value chains, both secondary and primary data were considered. Secondary data were obtained from reports, articles, records, publications etc., of state government departments, state agencies and research centres specialized in maize research in Telangana. Primary data were obtained in personal consultation with officials in state agriculture department and officers from state agencies especially PACS, DCMS, MARKFED, warehouse corporations, market committees etc.

RESULTS AND DISCUSSION

Despite the less demand for maize with most stocks and warehouses in full capacity and regardless of the state government recommendations to not to grow maize, farmers continued to grow maize in most parts of Telangana, since it was a less water demanding crop requiring less management with minimal costs.

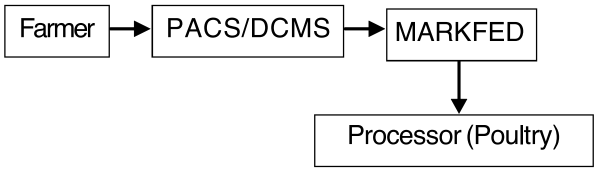
It has been observed that there were five value chains existing in the state from sampled districts as represented below:

Value chain- I



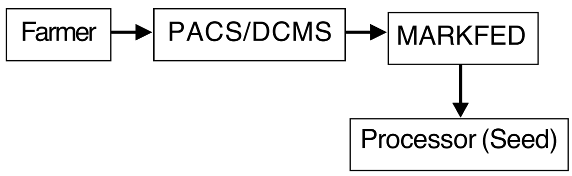
It can be seen from the above representation that, in this dominant value chain, maize was procured from maize producers by Telangana State Cooperative Marketing Federation (TS MARKFED) at Rs. 1760/- per quintal through Primary Agriculture Cooperative Societies (PACS) and District Cooperative Marketing Societies (DCMS). Further, from MARKFED, poultry farmers procured maize through farmer cooperatives via National Federation of Farmers Procurement, Processing and Retailing Cooperatives of India (NACOF). Maize was supplied to poultry farmers at subsidized rate of Rs 1525/- through farmer cooperatives. Positive aspect of this value chain was to farmers with assured returns in their bank accounts and least involvement of informal middlemen. But the dominant drawback was losses to the MARKFED as demand was very less for maize in the country. There was a great difference between the price at which maize is procured and the price at which maize was sold by the MARKFED. The NACOF just served as regulated channel between MARKFED and poultry farmer cooperatives for supplying maize.

Value chain-II



Not only poultry farmers, certain industry firms *viz.*, Kohinoor hatcheries, Vimala feeds were prominent buyers from MARKFED during the market seasons of 2019-20. The purchase was mainly through online tenders from MARKFED site. Apart from these, other major buyers were Venkateshwara hatcheries, Sneha farms, Suguna foods, Gouthami hatcheries, Vivin farms etc. Most of these firms were mainly involved either in broiler and layer business or both, whereas larger firms such as Suguna had more diversified activities and services with wider networks and partnerships with poultry farmers, investors and exports across India. We can comprehend from this value chain that, these industry firms who have a major stake in poultry business scout many options in procuring maize as per their requirements. Some of them obtain maize from neighbouring states too. This means though there is surplus stock of maize with T S MARKFED, some processors in the state prefer getting input from other sources. Under such situations, there will be big loss to the state governed MARKFED in disposing of maize. One positive aspect of this value chain was certain large firms like Suguna enabled poultry farmers across India to set up successful poultry business under their supervision with contract system.

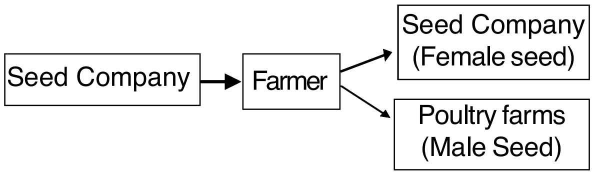
Value chain-III



In this value chain also, maize from sample districts was routed to MARKFED through PACS as observed in the above value chains. From MARKFED few seed processors *viz.*, Vimala seeds obtained maize through online tenders. Maize was sold at the same price of Rs 1525/- to these processors. Apart from Vimala seeds, others included small scale food processors *viz.*, V H agro foods, Nutricorn etc., who added some value and sold maize in edible forms. It was observed that these seed and food processors also constituted important players in maize value chain but the channels through which maize moved in these chains was relatively disorganized.

Seed Company (Female seed)

Value chain-IV



In some of the sampled villages of the study, some maize growers have grown hybrid maize on contract agreements with private seed companies, wherein all the operations right from supplying input seeds, farm activities till harvest were supervised by company agents. The company provided them with male and female seed. After harvest only female seed was procured back by the company. The additional male seed was sold to nearby poultry farms by farmer himself.

Value chain- V

It has already been noted from first value chain that during the market seasons of 2019-20, maize has been procured from farmers by PACS/DCMS on behalf of MARKFED through the establishment of procurement centres at village level. This was observed with the closure of informal markets and restricted transport regulations laid down by the government as precautionary measures against COVID. But prior to these regulations, most farmers sold their produce to the middlemen/ traders (as represented above) who further handled maize as per their decision and profits. Mostly they sold maize immediately to the processors.

It was observed in most of the dominant value chains that, MARKFED has been a main agency in purchasing the maize from farmers. But before the outcome of COVID, majority of the farmers have sold their product to the middlemen/trader (as represented in fifth value chain) who further sold maize to the processors (mostly poultry units and few starch industries). Farmers opined that it was relatively easy for them to dispose of the maize quickly to the trader. Most farmers in the sampled villages were synchronised with "time" and "quality" demands of the trader. But farmers faced an issue of delayed returns when they sold their produce to these middlemen/ traders.

With the advent of COVID and the regulations governed by the state, during the *rabi* market seasons of 2019-20, 100 percent of the maize in sampled districts was procured by TS MARKFED. The government of Telangana had taken a decision to procure the maize from farmers under minimum support price (MSP) at Rs. 1760/- per quintal for FAQ (fair average quality) with the establishment of maize procurement centres (MPCs) at each village. TS MARKFED acted as state procurement agency for procurement of maize under MSP operations. Agricultural Extension Officer at village level looked after the procurement activities. All the necessary infrastructure such as maize cleaners, moisture meters, weighing scales, winnowing machines, polythene covers etc., were made available at MPCs. The quantity of maize procured from each farmer was not more than district average yield per acre i.e, 24.68 quintals per acre. Maize stocks in conformity with FAQ norms were only procured from the farmers. All the staff involved in procurement process were adequately trained on the FAQ norms, measurement of moisture content, weighment and packaging. Primary Agriculture Cooperative Societies (PACS) and District Cooperative Marketing Societies (DCMS) aided in procurement and transport of maize from farmers to the warehouses/ godowns on behalf of TS MARKFED. Preferably the procured maize was sent to warehouses/godowns under State Warehousing Corporation (SWC) or Central Warehousing Corporation (CWC).

From MARKFED, procured maize is distributed to various buyers through tenders. During 2019-20 market seasons, prominent maize buyers from MARKFED were National Federation of Farmers Procurement, Processing and Retailing Cooperatives of India (NACOF), V Care seeds, Vimala feeds, Kohinoor hatcheries (as represented in first, second and third value chains above). Despite the 2019-20 market seasons alone, the investigator probed other prominent buyers of maize during past years. It was observed that other major buyers were Venkateshwara hatcheries, Sneha farms, Suguna farms, Gouthami hatcheries, Vivin farms etc. In some of the sampled villages like vempet village of metpally mandal, Jagityal district, few sampled farmers have grown hybrid maize on contract basis with seed companies (as represented in fourth value chain above).

Government has taken a decision to supply maize at subsidized rate of Rs 1525/- per quintal to poultry farmers. But it also cautioned that the same maize shall not get recycled and reach procurement centres. Most of the poultry farmers in present investigation procured maize from MARKFED through farmer cooperatives via NACOF.

It was also observed that few feed manufacturers were hesitant to purchase maize from Telangana farmers as they were getting the chicken feed at a cheaper price from other states such as Karnataka, Maharashtra, Bihar, Rajasthan and Madhya Pradesh.

CONCLUSION

It has been observed that, establishment of procurement centres at village level eased the process of sale of maize. TS MARKFED being a nodal agency played an important role in mediating the sales through PACS/DCMS and giving assured returns to the maize growers. However, with less demand for maize in the country, it also suffered huge losses with the maize procurement. Hence efforts may be directed towards enabling farmers in choosing those crops that fetch good price in the market than the routine crops which further fosters a win-win situation to both farmers and the government.

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Research Article
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PROFILE CHARACTERISTICS OF THE RESPONDENTS SELECTED TO STUDY THE RASTRIYA KRISHI VIKAS YOJANA PROGARMME IN TELANGANA STATE

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ABSTRACT

A study was conducted to know the profile characteristics of the respondents selected to study the RKVY programme in Telangana state. Three districts were selected randomly i.e Adilabad district from Northern Telangana Zone, Mahaboobnagar district form Southern Telangana Zone and Warangal urban district from Central Telangana Zone. From each district 80 respondents from agriculture and allied sectors were selected. A total of 240 respondents selected randomly. Profile characteristics selected for the study are age, education, farm size, farming experience, trainings received, extension contact, information seeking behaviour, farm mechanization status, risk orientation, innovativeness, socio political participation, achievement motivation and subsidy orientation. Exploratory research design was followed in the study, Majority of the respondents had middle age (55.00%), educated upto primary school (46.25%), had small farm size (37.92%), possessed medium farming experience (45.41%), received medium level of training (40.41%), had medium level of extension contact (52.50%), information seeking behaviour (40.42%), farm mechanization status (53.34%), risk orientation (59.58%), achievement motivation (41.66%), high level of innovativeness (52.09%), subsidy orientation (47.08%) and had low level of socio-political participation (45.00%).

The Food grain production in India which could not meet the demand of 35 to 40 crore population during 1950s gradually attained a level of exceeding the demand of more than 100 crore population by the beginning of 2000. Implementation of series of agricultural development programmes by government coupled with coordinated efforts of several research organizations, universities, councils and developmental departments in the field of agriculture made this achievement possible. All the agricultural development programmes during the earlier years were confined specially to a single objective. This strategy lacked convergence of various programmes and schemes of agriculture and allied sectors leading to steady deceleration of agricultural growth. At this juncture, National Development Council (NDC) strongly felt the need to have a scheme that could congregate all the farming activities and revive agricultural growth in the country. National Development Council in its 53rd meeting launched Rastriya Krishi Vikas Yojana (RKVY) on 29th May, 2007 and implemented during 11th Five Year Plan (FYP) by all the states and Union Territories of India with tenure of five years to enhance the agriculture growth.

During 11th and 12th five-year plan period tremendous changes has been occurred in agriculture and allied sectors in Telangana state due to RKVY programme interventions by providing crores of funds to the state for increasing annual agriculture growth rate by effective implementation and utilization of various interventions under RKVY. The objective of present study is to know the profile characteristic status of the beneficiaries under RKVY and how it influences the utilization of various interventions available under RKVY and maximization of returns in agriculture and allied sectors.

MATERIAL AND METHODS

Exploratory research design was adopted for the study. Telangana was selected purposively for the study as the RKVY programme is being implemented in the state. All the three zones of state were selected purposively and three districts were selected randomly i.e Adilabad district from Northern Telangana Zone, Mahaboobnagar district form Southern Telangana Zone and Warangal Urban district from Central Telangana Zone. From each district four mandals were selected randomly and from each mandal 20 respondents were selected randomly from agriculture and allied sectors. A total of 240 respondents selected randomly. The profile characteristics of the respondents selected for the study are, age, education, farm size, farming experience, trainings received,

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extension contacts, information seeking behvaiour, farm mechanization status, risk orientation, innovativeness, socio political participation, achievement motivation and subsidy orientation.

The respondent for the study is operationalized as the beneficiary of RKVY programme from 2014-15 to 2019-20 performing the activities of agriculture and allied sectors.

RESULTS AND DISCUSSION

Table 1. Distribution of respondents according to their profile characteristics (n=240)

S.No	Particulars	Category	Class Interval	Frequency	Percentage
1	Age	Young age	20-36	90	37.50
		Middle age	37-53	132	55.00
		Old age	54-70	18	07.50
2	Education	Illiterate	0	8	03.33
		Primary school	1	111	46.25
		High school	2	80	33.34
		Intermediate	3	29	12.08
		Under graduation	4	8	03.33
		Post-graduation and above	5	4	01.67
3	Farm size	Marginal farmer	Below 1 ha	44	18.33
		Small	1-2 ha	91	37.92
		Semi medium	2-4	67	27.92
		Medium	4-10	28	11.67
		Large	10 ha and above	10	4.17
4	Farming experience	Low	2-15	104	43.34
		Medium	16-29	109	45.41
		High	30-43	27	11.25
5	Training received	Low (1 Training)	1	80	33.34
		Medium (2 Trainings)	2	97	40.41
		High (3 and above Trainings)	3	63	26.25
6	Extension contact	Low	8-12	74	30.84
		Medium	13-17	126	52.50
		High	18-22	40	16.66
7	Information seeking behaviour	Low	4-9	67	27.92
		Medium	10-15	97	40.42
		High	16-21	76	31.66
8	Farm mechanization status	Low	0-3	91	37.91
		Medium	4-7	128	53.34
		High	8-11	21	08.75
9	Risk orientation	Low	11-13	59	24.58
		Medium	14-16	143	59.58
		High	17-19	38	15.84
10	Innovativeness	Low	16-20	31	12.91
		Medium	21-25	84	35.00
		High	26-30	125	52.09

S.No	Particulars	Category	Class Interval	Frequency	Percentage
11	Socio political participation	Low	1-4	108	45.00
		Medium	5-8	98	40.84
		High	9-12	34	14.16
12	Achievement motivation	Low	15-19	50	20.84
		Medium	20-24	100	41.66
		High	25-29	90	37.50
13	Subsidy orientation	Low	15-18	42	17.50
		Medium	19-22	85	35.42
		High	23-27	113	47.08

It is evident that, majority (55.00%) of the respondents were belonged to middle age followed by young (37.50%) and old (7.50%) age categories. Usually, farmers of middle aged are enthusiastic feel responsible and are more efficient than the younger and older ones and more active in performing agricultural practices. This result is in accordance with the results of Kalamkar *et al.* (2015) and Sonam *et al.* (2020).

Most of the respondents were educated up to primary school level (46.25%) followed by high school (33.34%), intermediate (12.08%), post graduation and above (01.67%) and illiterate and under graduation (03.33%). The probable reason might be due to the facilities available for education in the study area were upto primary school only and might be due to poor economic status of the family. Higher education is not attained as the importance of formal education is not realised. This result is in accordance with the results of Kalamkar *et al.* (2015) and Sonam *et al.* (2020).

Most (37.92%) of the respondents had small size of land holding followed by semi medium (27.92), marginal (18.33%), medium (11.67%) and large farm size (4.17%) categories respectively. Most of the respondents possessed small land holding to marginal land holding. This was due to the fragmentation of ancestral land holding from generation to generation leading to sub division of land to small size of land holdings. This result is in accordance with the results of Sahil *et al.* (2014) and Sonam *et al.* (2020).

Most (45.41%) of the respondents had medium level of farming experience followed by low (43.34%) and high (11.25%) levels of farming experience. The probable reason might be that most of farmers were middle and young aged, they might have less number of years of farming experience because of age and farming experience interlinked. If the respondents age was increased automatically increase the experience in their respective field. This result is in accordance with the results of Sahil *et al.* (2014).

Most (40.41%) of the respondents had received medium level of trainings followed by low (33.34) and high (26.25%) category trainings. Hence, from the above result, it could be concluded that most of respondents had received medium to low number of trainings. This result could be due to the primary to high level of formal schooling with small farm size, medium level of extension contacts of the respondents and busy with regular farm operations related activities etc, and lack of awareness about the extension methodologies to get information on new technologies. This result is in accordance with the results of Kalamkar *et al.* (2015).

Majority (52.50%) of the respondents were found to possess medium extension contact followed by low (30.84%) and high (16.66%) extension contact categories. The probable reason for the above trend might be that, the majority of farmers were educated upto primary school with small and marginal land holdings, hence would not contact the officials of state department of agriculture and allied departments. This result is in accordance with the results of Sonam *et al.* (2020).

Most (40.42%) of the respondents were possessed medium level of information seeking behaviour, followed by high (31.66%) and low (27.92%) level of information seeking behaviour. Majority of respondents fell under medium information seeking behaviour. These respondents were seeking information from different informal and formal sources. Most of the respondents contacting with progressive and fellow farmers for information under informal sources, whereas in formal sources respondents get information through various grassroot level awareness programmes and kisan melas etc. This result is in accordance with the results of Mankar *et al.* (2013) and Latha (2015).

Majority (53.34%) of the respondents were possessed medium farm mechanization status, followed by low (37.91%) and high (08.75%) farm mechanization status categories. The result indicate that respondents had the scope to utilize the farm implements as they have medium status of farm mechanization. And every farmer cannot afford to have all required farm machinery and it is not economical in terms of its maintenance and use. This result is in accordance with the results of Kalamkar *et al* (2015).

Majority (59.58%) of the respondents had medium level of risk orientation, followed by low (24.58%) and high (15.84%) level of risk orientation. The reason behind such type of result in the study area could be taking up the calculated risk of crop diversification from traditional cultivation to modern farming to overcome the risk and also practicing new livestock rearing techniques for higher returns. During recent years the farmers were taking up agriculture in an integrated mode by combing all allied components to avoid the risk involved in single enterprise. This result is in accordance with the results of Kale *et al.* (2012) and Sonam *et al.* (2020).

Majority (52.09%) of the respondents had high innovativeness followed by medium (35.00%) and low (12.91%) level of innovativeness. The above result indicated that most of the respondents of Rastriya Krishi Vikas Yojana belonged to high innovativeness category because they adopt the innovation as and when brought to their notice, and the fact that in the study area most of the innovations like farm implements, new crop varieties, quality seeds, crop management techniques and other inputs were given under subsidy to the farmers. However, the possible reason might be that the respondents with primary education, medium level of extension contacts and medium level of trainings received were able to update their knowledge and skills time to time and ready to accept the new technologies in their farming. This result is in accordance with the results of Latha (2015).

Most (45.00%) of the respondents had low socio-political participation followed by medium (40.84%) and high (14.16%) socio political participation. This might be due to unaware about the advantages of becoming members, busy with activities like agriculture and income generation activities and less interest to participate in social activities. This result is in accordance with the results of Sonam *et al.* (2020).

Most (41.66%) of the respondents had medium level of achievement motivation, followed by high (37.50%) and low (20.84%) level of achievement motivation. The result might be due to personal and situational factors which may influence their achievement motivation. The medium level of risk orientation and information seeking behaviuor of respondents might have resulted low achievement motivation. This result is in accordance with the results of Jayanta Roy (2012).

Most (47.08%) of the respondents were found in high level of subsidy orientation, followed by medium (35.42%) and low (17.50%). This result might be due to the fact that the implementation of RKVY with its basic conjecture of holistic approach assigns due importance on subsidy provision for the resource poor farmers. The subsidy part under RKVY as well as other schemes in the study area is being provided in material form. It acts as a motivational force to adopt new practices enthusiastically in large scale by utilising benefits and get higher returns in agriculture and allied sectors. This result is in accordance with the results of Kalamkar *et al.* (2015).

CONCLUSION

Majority of the respondents belonged to middle age, had primary school education with small farm size, less farming experience, medium level of trainings received, medium extension contact, information seeking behaviour, farm mechanization status, risk orientation, achievement motivation and high level of innovativeness, subsidy orientation and low level of socio political participation.

This shows there is a greater need to increase the literacy levels by providing functional literacy programmes along with developing awareness among the farmers on importance of extension contacts and information seeking behaviour. There is every need to improve the profile of the respondents to make them to understand the guidelines and to derive maximum benefits from the RKVY programme.

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STUDIES ON SPATIO-TEMPORAL AND PHYTOHORMONAL EXPRESSION PATTERN OF *MTP2* PROTEIN AND ITS CHARACTERIZATION ACROSS DIFFERENT PLANT SPECIES

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Zinc is an essential micronutrient involved in a wide range of physiological processes of plants (Marschner, 1993). Even though it is required for plant growth, the excess amount of Zn causes toxic effects to plants. It is known that during Fe deficiency, the uptake of Zn is induced which leads to the accumulation of the excess amount of Zn in the plant cytoplasm. The plant has evolved an efficient mechanism in detoxifying the excess Zn uptake during Fe deficiency conditions, of which vacuoles are identified to be the main storage and detoxifying organelles for Zn excess in the cytoplasm (Gustin *et al.,* 2009). Zinc is normally available to the plants in its oxidized form Zn^{2+} from the soil through the mass flow and diffusion mechanism by roots (Rattan and Deb, 1981). Availability of Zn is high in low acidic pH wherein the high pH reduces its availability in soil and the root plasma membrane transporters reported for major uptake of Zn from the soil (Marschner, 1993).

Zinc uptake from the soil is mediated by the rhizosphere acidification process followed by solubilization. Plant roots uptake the zinc in the form of Zn^{2+} or the Zn-ligand complex (Von Wiren *et al.,* 1996). In the Zn^{2+} form of zinc uptake, the H^+ ions and organic acids are released by the plants to lowers the ph of the soil, which mediates the solubilization of Zn complexes in the soil. In Zn-ligand complexes, the phytosiderophores are effluxed into the soil which forms a stable complex with zinc ions. Nicotianamine (NA) was reported to be the major chelator, involved in the uptake of Zn ions from the soil (Trampczynska *et al.,* 2006; Haydon and Cobbett, 2007). Many genes have been reported to encode transporter proteins in the Zn uptake and transport mechanism. Among the reported zinc transporter families, *ZIP* (Zinc, Iron permease family/ZRT-IRT-like proteins) family (Grotz *et al.,* 1998), the *MTP* (Metal tolerance proteins) and, *HMA* (Heavy metal ATPases) family are the major ones. In Arabidopsis many *ZIP* proteins *i.e., ZIP1-4, ZIP7, ZIP11-12*, and *IRT3* are involved in zinc uptake from the soil (Kramer *et al.,* 2007), of which *IRT3* was well-studied plasma membrane transporter. The *ZIP* proteins are reported to be involved in the Zn detoxification and homeostasis mechanism process. *HMA* families of transporters are involved in the transport of metals in the plants and are known as P_{1B}-type ATPases. In Arabidopsis, eight *HMA*s have been identified, out of which *HMA1-HMA4* are belonging to Zn/Co/Cd/Pb subgroup (Cobbett *et al.,* 2003).

Apart from the above transporters *MTP1* and *MTP3* are reported to be involved in the sequestration of Zn ions into the vacuoles from the cytoplasm with the efflux of H^+ ions to the cytosol (Kobae *et al.,* 2004; Desbrosses-Fonrouge *et al.,* 2005). These belong to the cation diffusion facilitator family of proteins and are reported to be localized on the tonoplast membrane of the vacuole of the cell. To date, twelve members of *MTP* family transporters have been reported in Arabidopsis of which *MTP1* and *MTP3* were well studied. *MTP1* promoter activity is highest in young leaves, whereas *MTP3* expression is undetectable in shoots. Moreover, *MTP3* expression is very low under normal growth conditions and strongly increased in response to Fe deficiency and upon

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exposure of seedlings to excess Zn (Arrivault *et al.,* 2006). However, *MTP1* and *MTP3* have opposite effects on Zn accumulation.

Physiological Zn deficiency of *Arabidopsis thaliana* shoots results in increased root transcript levels of the membrane transport protein-encoding genes *METAL TRANSPORT PROTEIN2* (*MTP2*) and *HEAVY METAL ATPASE2* (*HMA2*), which are unresponsive to the local Zn status of roots. *MTP2* and *HMA2* act additively in the partitioning of Zn from roots to shoots. When compared to *MTP1* and *MTP3*, few studies were conducted on *MTP2* transporter following the Zn homeostasis pathway. Based on this background, the identification of *MTP2* transporter proteins in different crops, conserved motif sequence, evolutionary relationships, the expression pattern of MTP2 gene at different growth stages and to the plant hormone treatment were analyzed *insilico* in the present study, using online bioinformatics tools and plant databases.

The Uniprot ID, Q10LJ2 coding for the Oryza sativa japonica group *MTP2* protein sequence was downloaded from the UniProt database. The sequence was used as a query for the identification of similar proteins in other related crops with an E-value of 0 and more than 80% similarity. Similar sequences were identified in *Hordeum vulgare* (81.22%), *Aegilops tauschii* (82.11%), *Brachypodium distachyon* (81.89%), *Triticum dicoccoides* (82.68%), *Zea mays* (87.75%), *Oryza brachyantha* (88.72%), *Panicum virgatum* (86.47%), *Sorghum bicolor* (86.59%), *Panicum hallii* (87.10%), *Dichanthelium oligosanthes* (86.71%), *Setaria italica* (84.23%), and *Setaria viridis* (83.94%) crops with more than 80% similar identity (Table 1).

Table 1: Details of different crops with Protein IDs and similarity percentage downloaded from NCBI

Protein ID	Crop name	Similarity %
XP_015628702.1	Oryza sativa Japonica Group	100.00
KAE8781701.1	Hordeum vulgare	81.22
XP_020193507.1	Aegilops tauschii	82.11
XP_003557927.1	Brachypodium distachyon	81.89
XP_037430426.1	Triticum dicoccoides	82.68
XP_015689891.2	Oryza brachyantha	82.72
XP_039830393.1	Panicum virgatum	86.47
XP_021307383.1	Sorghum bicolor	86.59
PWZ53216.1	Zea mays	87.75
XP_025794726.1	Panicum hallii	87.1
OEL27878.1	Dichanthelium oligosanthes	86.71
XP_004984402.1	Setaria italica	84.23
XP_034573611.1	Setaria viridis	83.94

The conserved motifs among the above 13 *MTP2* protein sequences from different crops were identified using a MEME server with a minimum of 5 motifs and maximum width of 50. The first motif sequence identified was GTSLYLDVHIEVYPFLSVS AAHDIGETVRHQIQKEH NQVAEVFIHIDPSY, the second motif sequence was YRAAKAPRDKEHPYGH GKFESLGALGISSMLLVTSGGIAWHAFEVLQGVM, the third motif sequence, MILKAGIQTGYES VLELVDAAVDPSLLEPIKETILKVDGVKGCHRLRGRK, and the fourth motif sequence was LYWITKRAGEKE GSGLMKANAWHHRADAISSVVALVGVGGSILGL PLLDP.

Moreover, the sequence of the fifth motif discovered was IISSHFSKKMSLEHLMLHYVQG RVLLQVQVSMSPEILIRDAMEIAKQAEE and all the motifs identified were 50 amino acids in length (Figure 1). All the 13 protein sequences from the different crops have shared the five conserved motifs and their position in the above 13 crops was elucidated in Figure 2. The multiple sequence alignment and evolutionary analysis of *MTP2* protein in different crops were done using the CLUSTALW online tool. The phylogenetic tree was executed using the PhyML bootstrap method using the percent scoring method. The *MTP2* proteins showed 70-100% of similarity among the 13 proteins. The phylogenetic tree was divided into four main groups based on the tree topologies (Figure 3). In group, A four *MTP2* proteins of *Brachypodium distachyon, Hordeum vulgare, Triticum dicoccoides, Aegilops tauschii* have formed a cluster. In group B, *Oryza sativa Japonica* Group and *Oryza brachyantha* formed a cluster, wherein group C, *Sorghum bicolor,* and *Zea mays* formed a cluster. Two proteins of *Panicum sps*, two proteins of *Setaria sps,* and one protein of *Dichanthelium oligosanthes* formed a cluster in group D.

The RAP locus ID of *MTP2* of *Oryza sativa* was used as a query in the Ricexpro database for Spatio-temporal expression analysis. The overview of the expression pattern of *MTP2* protein in specific tissues and organs at various growth stages in the entire Spatio-temporal developmental cycle from the transplanting to harvesting was analyzed (Sato *et al.,* 2012). The expression profile of the *MTP2* gene in 48 samples of various tissues in three replicates was represented in Figure 4. The higher expression of *MTP2* protein was observed in ovary tissue, five days after flowering and followed by the root tissue at the vegetative stage at 12.00 AM. The lower expression of the protein in rice was noted in endosperm tissue at 7, 10, 14, 28, 42 days after flowering (Figure 4).

Apart from the above analysis, an overview of expression of *MTP2* gene in root and shoot of rice seedling treated with hormones namely, abscisic acid (ABA), gibberellic acid (GA3), indole-3-acetic acid (IAA), brassinolide (BL), trans-zeatin (tZ) and jasmonic acid (JA) was analyzed (Sato *et al.,* 2012). The expression pattern of *MTP2* in roots to different hormones was analyzed at 15min, 30min, 1h, 3h, and 6h of incubation period and in shoot samples at 1h, 3h, 6h, and 12hr of incubation with three replicates. The total RNA samples were labeled with Cy3 9mock treatment) and Cy5 (hormone treatment) and time course expression profile for the gene is shown as the log-ratio of signal intensity (log2 Cy5/Cy3) in Figure 5. From the figure, it is reported that at 6hr of abscisic acid, the expression of *MTP2* protein was upregulated in root tissue wherein it was found to be downregulated in shoot tissue. The expression of the gene was reported to be similar at 1h, 3h, and 6h gibberellic acid treatment of both root and shoot, but at 12h after treatment in the shoot, slight downregulation was recorded. In the case of IAA, tZ, and BL hormone treatment the expression pattern was the same in root and shoot tissues. The JA treatment induced the expression of *MTP2* protein at 6h in root wherein the shoots, the expression was induced at 12h of treatment.

The Spatio-temporal expression analysis of *MTP2* protein revealed the importance of the protein at the vegetative state of root and at ovary tissue when plants grown under normal conditions. Further, biotic and abiotic stresses are detected by the plant cell wherein the plant hormones act as a signaling molecule in activating the defense mechanism in them. The expression pattern studies of *MTP2* protein to different phytohormonal treatment results revealed the connection between the expressions of *MTP2* protein to plant hormones which indicated its downregulated expression towards JAs treatment. In the case of ABA treatment in roots, the expression was slightly upregulated at 3h of treatment, and in the shoot, the downregulation was recorded at 6h of treatment. Based on these insilico results, it is understood that, more research in identifying the protein interacting partners, protein structural studies for functional characterization is required.

	Logo	Evlaue ?	Sites ?	Width ?
1.		3.2e-570	14	50
2.		3.4e-518	14	50
3.		3.6e-511	14	50
4.		4.3e-511	14	50
5.		2.9e-451	13	50

Figure 1: Identified conserved motifs in *MTP2* proteins among 13 plant species

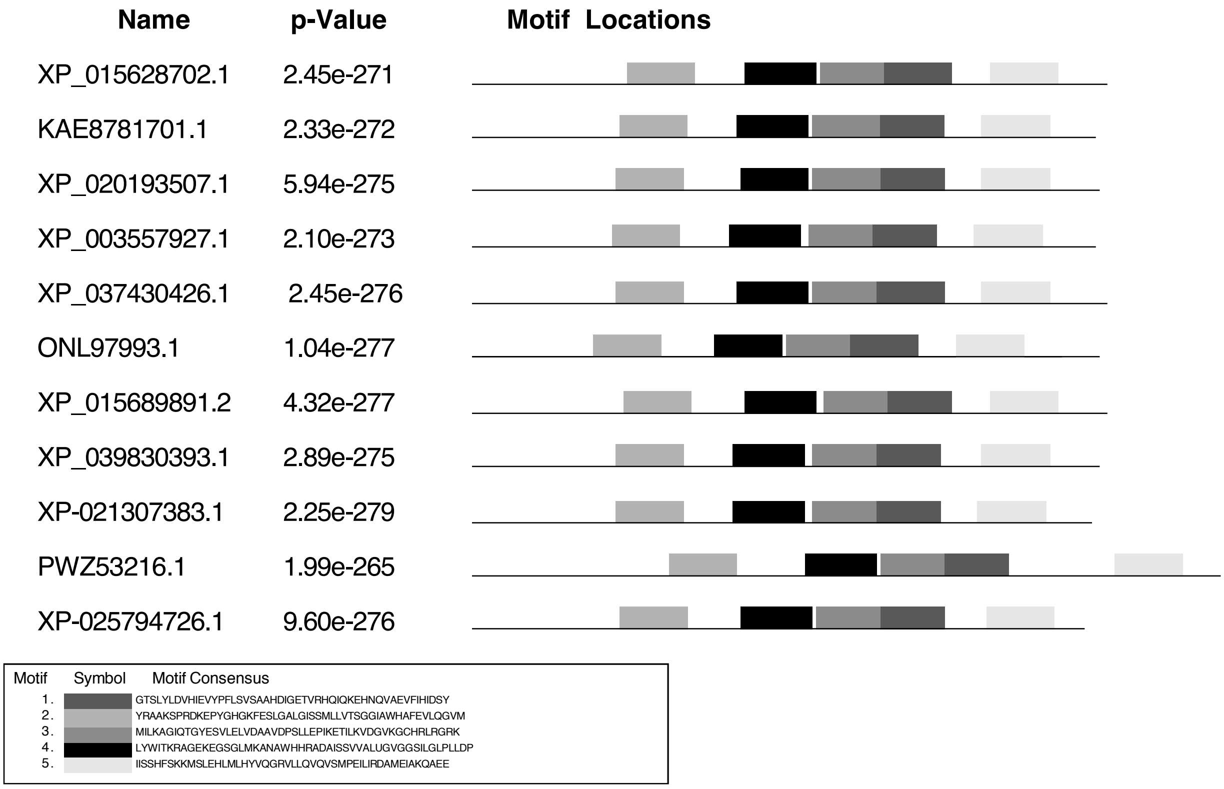

Figure 2. Motif locations identified in *MTP2* proteins among 13 plant species

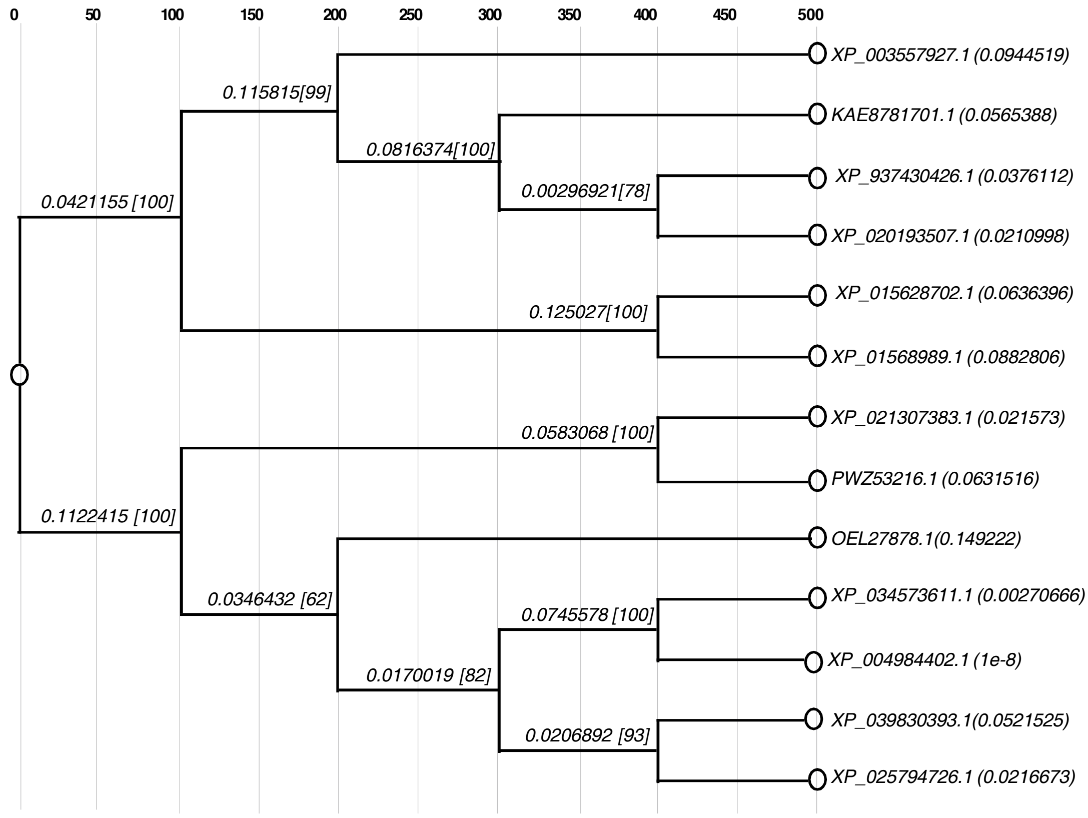

Figure 3. Phylogenetic tree constructed from *MTP2* of 13 plant species

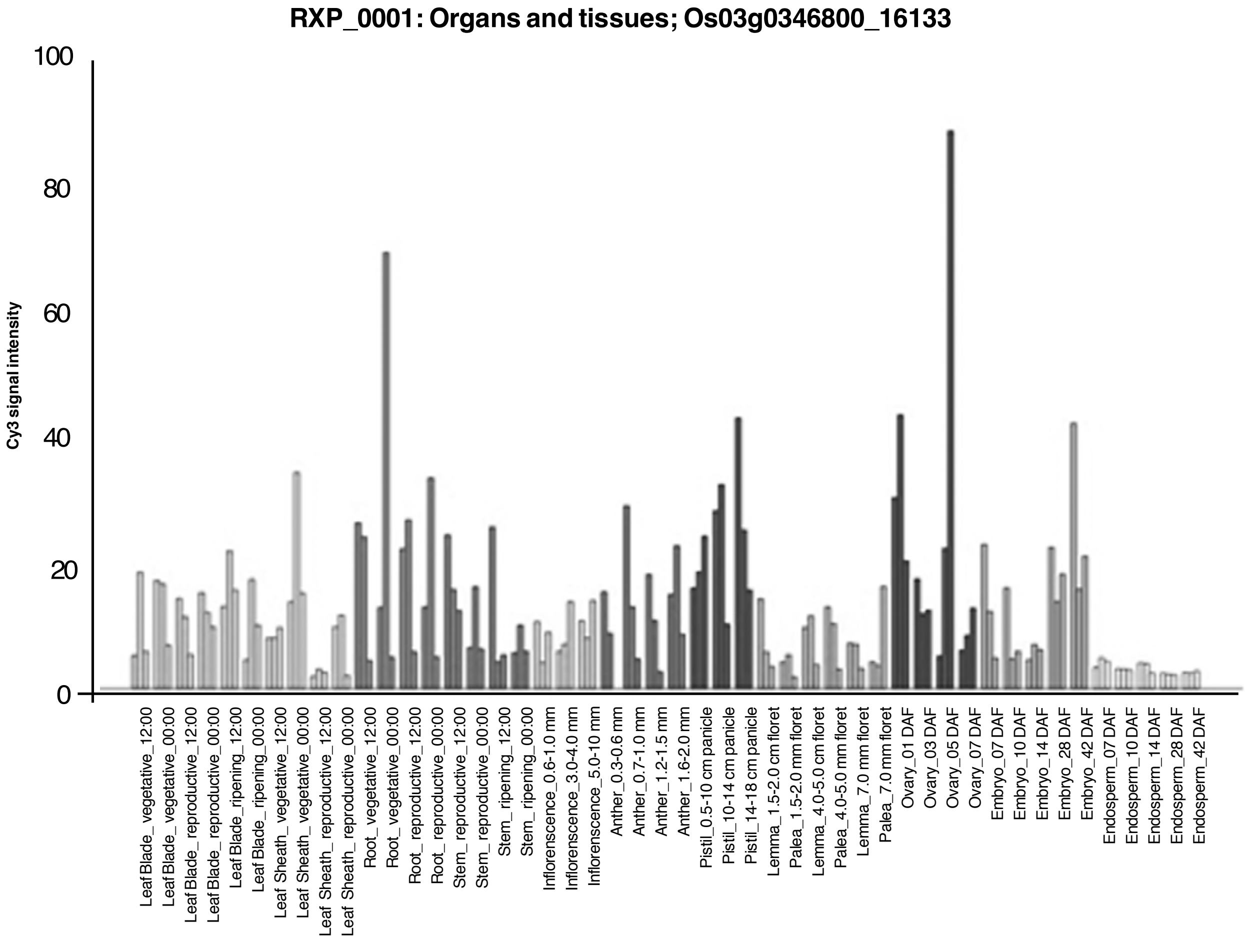

Figure 4. Graph indicating the expression of MTP2 in different developmental stages under normal growth conditions

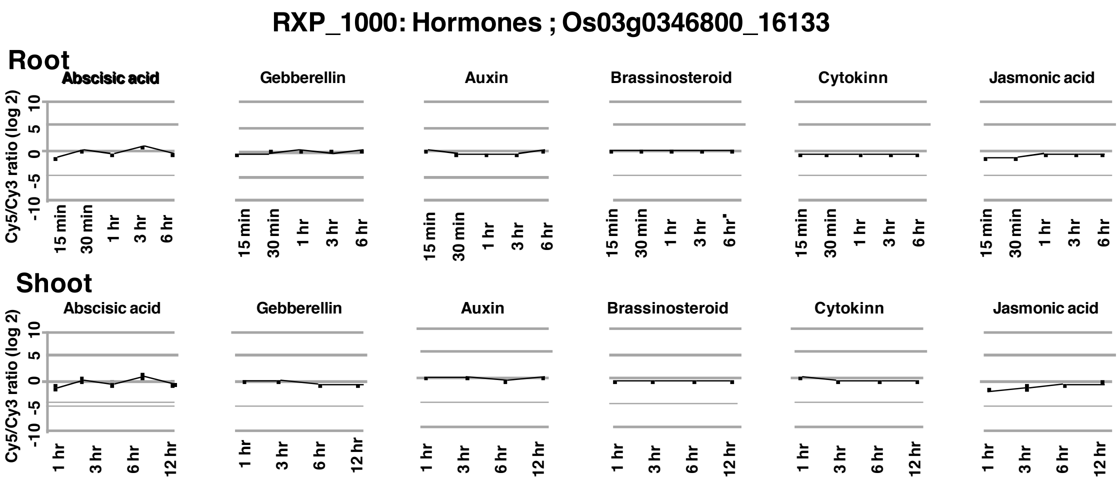

Figure 5. Graphs indicating the expression of *MTP2* protein in root and shoot tissues under plant hormonal treatment

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Research Note
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ECONOMIC ANALYSIS OF MARKETING OF GRAPES IN ARGHANDAB DISTRICT, KANDAHAR PROVINCE, AFGHANISTAN

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The cultivation of domesticated grapes began 6,000-8,000 years ago in Southern Turkey, spreading to Northern Africa, Europe, Asia and North America. More grapes are grown in Afghanistan than any other fruits, comprising nearly half of the total fruits produced, thereby playing an important role in the agricultural economy. Each year grapes are exported (both fresh and dried) to countries such as Pakistan, India, the UAE and Central Asia. Grapes in Afghanistan are consumed fresh, dried and in the form of grape juice. The area of grapes in Afghanistan is about 78405 hectares (2016) of which 90 per cent of this growing area is located in the provinces of Kandahar, Helmand, northern and central zones, (Samadi, 2011). Production of grapes was estimated around 58,000 tons in 2015. Average farm yields are approximately 12.48 tons/ha (United Nation ESCAP, 2018). More than 100 varieties of grapes are grown in Afghanistan, but commercial production focuses on three local varieties; Shindokhani, Kishmishi and Taifi. The grapes are widely famous in Kandahar province as it is main production area for its high quality and productivity. Grapevine orchards are mainly concentrated in Arghandab district with an average yield at about 12.48 tons/ha in Arghandab district from which grapes are supplied to other provinces of the country. Domestic production accounts for the largest part of domestic consumption since very low quantities are imported from abroad. Grapes are the most produced commodity among fruits and vegetables in the country but Afghanistan is barely quoted as a producing country. The area under grapes is gradually increasing in the Arghandab district. So far very few studies have been conducted on the supply chain of grapes in Arghandab district. A detailed study in this regard would help the farmers to have first-hand knowledge of the marketing issues and outcome of the study would be rewarding to the farmers. Hence, this study was undertaken.

The cultivation of Grapes in Kandahar province is concentrated mainly in the district of Arghandab because of the favorable conditions for the production and marketing of grapes, hence the district was selected purposively for the present study. In the district of Arghandab five villages with highest area under grapes purposively were selected. The villages thus selected were Nagahan, Khaisrow, Tabin. Khaishki and Kowack. From the villages so selected 6 farmers from each village representing for grapes were randomly selected. Making the size of sample farmers as 30. The primary data was collected from farmers through personal interview method using a schedule. The primary data pertain to the year 2017-18.

Marketing cost and margin

The concurrent margin has been estimated, as it is the difference between the price prevailing at successive stages of marketing at a given point of time, e.g., the difference between farmer's selling price and retail price on a specific date is the total concurrent margin. To study the existing marketing system, marketing margins and cost for different channels in the selected markets the price spread was estimated by using the following formulae.

Market Margin of i^{th} Middlemen (A_{mi}) = P_{ri} (P_{pi}+C_{mi})

Where,

A_{mi} = Market margin of i^{th} middlemen

P_{ri} = Total value of receipts per unit (Sale price)

P_{pi} = Purchase value per unit (Purchase price)

C_{mi} = Cost incurred on marketing per unit

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Total marketing cost

$C = C_f + C_{m1} = C_{m2} + C_{m3} + \ldots\ldots + C_{mn}$

Where,

C = Total cost of marketing of the commodity

C_F = Cost paid by the producer from the time the produce leaves the farm till he sells it

C_{mi} = Cost incurred by the i^{th} middlemen in the process of buying and selling the produce

Producer's price

The producer's price is the net price received by the farmer at the time of first sale. This is the equal to the wholesale price at the primary assembling center, minus the charges borne by the framers in selling by using the following formulae.

$P_f = P_A - C_f$

Where,

P_A = Wholesale price

C_f = Marketing cost incurred by farmer

P_f = Producer's price

The supply chain of grapes which were identified in five various channels, were mostly considered for farmers to follow, hence during the primary data the following channels were identified and presented below. The grapes in the study area were marketed through five channels from producers to the ultimate consumers. The channels are as follows:

Channel I : Producer - Wholesaler - Retailer - Consumer (48.8 %)

Channel II : Producer - Exporter - Retailer - Consumer (26.6%)

Channel III : Producer - Market yard - Wholesaler - Retailer - Consumer (16.3%)

Channel IV : Producer - Consumer (5%)

Channel V : Other specify (Producer - Retailer - Consumer) (3.3%)

In Channel (I) the producer sold the grapes to the wholesaler in the garden just before harvesting who moved the produce to the retailer and directly to consumer. In this channel 48.8 per cent of the produce was sold.

In this channel (II) exporter figured. The exporter who was also involved in export trade undertake purchases from farmers and then sold the produce to counterpart in the import market. In the import market from exporter the fruit reached consumer through retailers.

In channel (III), market yard facilitated the transactions. The produce was sold through open auction by the farmers to the wholesalers, who in turn sold to the retailer, before the produce reached the consumer.

Channel (IV) presents the picture of consumer buying directly from the farmers.

In channel (V) retailers contacted the producers and have undertaken the purchases before selling to the consumers. Most of the producers were unable to sell the products through above mentioned channels, hence the producer sold the produce as retailers, and sold the produce in carts in one side of the road.

1- Marketing costs for Grapes : Marketing costs are the sum total of costs incurred in the movement of produce and they include costs such as crate charges, transportation, market fee, commission charges etc. The concurrent margin has been estimated, as it is the difference between the prices prevailing at successive stages of marketing at a given point of time. The marketing costs incurred by producer as well as the market intermediaries in the marketing of Grapes were worked out for the marketing channels identified and presented in Table 1.

Table 1. Marketing costs for Grapes (Rs/Qt)

S.N.	Particulars	Channel I	Channel II	Channel III	Channel IV	Channel V
1	**Producer**	-	-	-	-	-
i	Crate charges	497.62 (66.26)	497.62 (66.26)	497.62 (66.26)	497.62 (75.34)	497.62 (75.34)
i	Transportation	90.47 (12.04)	90.47 (12.04)	90.47 (12.04)	90.47 (13.69)	90.47 (13.69)
iii	Labour expenses	72.38 (9.63)	72.38 (9.63)	72.38 (9.63)	72.38 (10.95)	72.38 (10.95)

S.No.	Particulars	Channel I	Channel II	Channel III	Channel IV	Channel V
iv	Commission agent's fee	90.47 (12.04)	90.47 (12.04)	90.47 (12.04)	0	0
	Total costs	**750.94 (100)**	**750.94 (100)**	**750.94 (100)**	**660.47 (100)**	**660.47 (100)**
2	**Wholesaler**	-	-	-	-	-
i	Crate charges	497.62 (66.47)	-	497.62 (66.47)	-	-
i	Transportation	90.47 (12.08)	-	90.47 (12.08)	-	-
iii	Labour expenses	90.47 (12.08)	-	90.47 (12.08)	-	-
iv	Spoilage	70 (9.35)	-	70 (9.35)	-	-
	Total Costs	**748.56 (100)**	-	**748.56 (100)**	-	-
3	**Exporter**	-	-	-	-	-
i	Crate charges	-	542.86 (18.75)	-	-	-
i	Transportation	-	1221.42 (42.19)	-	-	-
iii	Labour expenses	-	678.57 (23.44)	-	-	-
iv	Marketing fee	-	226.19 (7.81)	-	-	-
v	Weighment charges	-	135.71 (4.68)	-	-	-
vi	Spoilage	-	89.80 (3.10)	-	-	-
	Total costs	-	**2894.55 (100)**	-	-	-
4	**Retailer**					
i	Crate charges	271.4 (38.58)	110.45 (29.04)	271.4 (38.58)	-	271.4 46.79)
i	Transportation	45.23 (6.43)	30.50 (8.02)	45.23 (6.43)	-	45.23 (7.79)
iii	Labour expenses	63.33 (9.00)	40.36 (10.61)	63.33 (9.00)	-	63.33 (10.91)
iv	Weighment charges	22.61 (3.21)	10.97 (2.88)	22.61 (3.21)	-	0
v	Spoilage	300.8 (42.76)	188.01 (49.43)	300.8 (49.43)	-	200 (34.48)
	Total Costs	**703.37 (100)**	**380.29 (100)**	**703.37 (100)**	-	**579.96 (100)**

From the above-mentioned table it is indicated that the sample farmers had incurred an amount of Rs. 750.94 in marketing one quintal of grapes towards crate charges, transportation, labour expenses and commission agent's fee. Crate charges was the major item accounting for 66.26 per cent of total cost. The wholesaler incurred an amount of Rs. 748.56 towards marketing costs comprising crate charges, transportation, labour charges and spoilage. For the retailer major costs were crate charges and spoilage. The total marketing costs incurred by retailer stood at Rs. 703.37, hence the various channels were reported from the table mentioned above.

Price spread in grapes marketing

The price spread analysis for grapes was carried out and the results are presented in Table 2.

Table 2. Price spread of grapes (Rs/Qt)

S.N.	Particulars	Channel I	Channel II	Channel III	Channel IV	Channel V
1	**Price received by producer**	1268.25 (28.90)	1268.25 (12.19)	1262.70 (28.81)	1369.20 (100)	1085.71 (39.92)
i	Marketing costs	750.94 (17.11)	750.94 (7.22)	750.94 (17.13)	660.47 (48.23)	660.47 (24.29)
i	Net price	517.31 (11.87)	517.31 (4.97)	511.76 (11.67)	708.73 (51.76)	425.24 (15.63)
2	**Wholesaler**					
i	Purchase price	1268.25 (28.90)	-	1262.70 (28.81)	-	-
i	Marketing costs	748.56 (17.05)	-	748.56 (17.08)	-	-
iii	Margin	523.8 (11.93)	-	523.8 (11.95)	-	-
3	**Exporter**					
i	Purchase price	**-**	1268.57 (12.20)	-	-	-
i	Marketing costs	**-**	2894.55 (27.83)	-	-	-
iii	Margin	**-**	3865.45 (37.14)	-	-	-
4	**Retailer**			-	-	-
i	Purchase price	2540.61 (57.89)	8028.57 (77.21)	2535.06 (57.84)	-	1085.71 (39.92)
i	Marketing costs	703.37 (16.02)	380.29 (3.65)	703.37 (16.04)	-	579.96 (21.32)
iii	Margin	1143.95 (26.07)	1988.78 (19.12)	1143.95 (26.10)	-	1053.42 (38.74)
	Total marketing costs	**2202.87 (50.20)**	**4025.78 (38.71)**	**2202.87 (50.26)**	**660.47 (48.23)**	**1240.43 (45.61)**
	Total marketing margins	**1667.75 (38.00)**	**5854.55 (56.30)**	**1667.75 (38.05)**	**-**	**1053.42 (38.71)**
	Consumer's purchase price	**4387.93 (100)**	**10397.64 (100)**	**4382.38 (100)**	**1369.20 (100)**	**2719.09 (100)**

An overview of the price spread analysis of grapes from above mentioned table showed that the producer's share in consumer's rupee was higher in channel IV that when the fruits were sold directly to consumers. The producer's share in consumer's rupee varied from 4.97 per cent to 51.61 per cent and minimum share was found in export trade. Across the channels highest margin was found in channel II for the exporters. Total marketing margins were highest in channel II both in term of absolute values and percentage terms. Consumer's price was least when the fruits were sold directly to the consumers.

CONCLUSION

Five marketing channels were found operating in grapes. Highest percentage of sales took place through channel I in grapes i.e. Producer- wholesaler- retailer- consumer. The grapes sample farmers had incurred an amount of Rs. 750.94 in marketing one quintal of grapes towards crate charges, transportation, labor expenses and commission agent's fee in channel I. Crate charges was the major item accounting for 66.47 per cent of total costs. An overview of the price spread analysis of grapes showed that the producer's share in consumer's rupee was higher in channel IV that when the fruits were sold directly to consumers. The producer's share in consumer's rupee varied from 4.97 per cent to 51.61 per cent and minimum share was found in export trade. Across the channels highest margin was found in channel II for the exporters. Total marketing margins were highest in channel II both in term of absolute values and percentage terms. Consumer's price was least when the fruits were sold directly to the consumers.

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- All graphs or diagrams should have clarity to represent the values and should be well explained
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- In case of lack of knowledge or inability to follow the instructions as above, one may request Editor for further help after sending original excel data sheet

9. **CONCLUSION:** Should be precise, focused to the objective not exceeding 100 words.
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Journals and Bulletins

Abdul Salam, M and Mazrooe, S.A. 2007. Water requirement of maize (*Zea mays* L.) as influenced by planting dates in Kuwait. Journal of Agrometeorology. 9 (1): 34-41.

Hu, J., Yue, B and Vick, B.A. 2007. Integration of trap makers onto a sunflower SSR marker linkage map constructed from 92 recombinant inbred lines. Helia. 30 (46): 25-36.

Books

AOAC. 1990. Official methods of analysis. Association of official analytical chemists. 15th Ed. Washington DC. USA. pp. 256.

Federer, W.T. 1993. Statistical design and analysis for intercropping experiments. Volume I: two crops. Springer – Verlag, Cornell University, Ithaca, New York, USA. pp. 298-305.

Thesis

Rajendra Prasad, K. 2017. Genetic analysis of yield and yield component in hybrid Rice *(Oryza sativa.* L). Ph.D Thesis submitted to Professor Jayashankar Telangana State Agriculutural University, Hyderabad.

Seminars / Symposia / Workshops

Naveen Kumar, P.G and Shaik Mohammad 2007. Farming Systems approach – A way towards organic farming. Paper presented at the National symposium on integrated farming systems and its role towards livelihood improvement. Jaipur, 26 – 28 October 2007. pp.43-46

Proceedings of Seminars / Symposia

Bind, M and Howden, M. 2004. Challenges and opportunities for cropping systems in a changing climate. Proceedings of International crop science congress. Brisbane –Australia. 26 September – 1 October 2004. pp. 52-54

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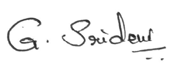

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