ISSN 2664-4010 (Print) & ISSN 2664-6730 (Online)
South Asian Research Journal of Agriculture and Fisheries
Abbreviated Key Title: South Asian Res J Agri Fish

| Volume-3 | Issue-5 | Sept-Oct -2021 | **DOI: 10.36346/sarjaf.2021.v03i05.002**

Original Research Article

Monitoring and Identification of Cotton Crop in Sirsa District Using Radar Spectral Signature

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Article History
Received: 02.09.2021
Accepted: 06.10.2021
Published: 11.10.2021

Abstract: Agriculture is the mainstay of Indian economy. The country has the second largest population in the world whose demand of food is sustained by agriculture. Geo-informatics plays a vital role in management of agricultural activities on sustainable basis. A Synthetic Aperture Radar (SAR) system operating in the microwave region of the electromagnetic spectrum has an ability of imaging the earth surface day and night even during cloudy weather. Present study was carried out for generation of radar spectral signature (RSS) of kharif season crops using multi-temporal Sentinel-1A, synthetic aperture radar (SAR) data acquisition in C-band with vertical transmit and vertical receive (VV) polarization. Multi-temporal Sentinel-1A SAR images (May to September) covering the all main phenological stages of crop were acquired. Due to the presence of multiple scatters within the crop volume scattering of radar energy occurs when the SAR beam penetrates the crop. In volume scattering multiple bounces and reflection from the different components of the crop occurs thus resulting in high backscattering values. Depending upon the backscattering values in multi-temporal SAR data the cotton crop is further segregated in two categories i.e. late sown and early sown cotton crop. SAR backscatter values for cotton and other associated major kharif season crops were noted on multi-temporal SAR data. Each crop has different date of sowing and growing pattern also having difference in crop biomass, moisture content, plant height, plant density per meter square. Due to this a significant difference in radar backscatter values for the different crops in multi-temporal SAR data was observed during their growing period. The results of the study demonstrate the potential of multi-temporal Sentinel-1A, SAR data for monitoring and identification of cotton crop.

Keywords: Backscatter, VV, Multi-temporal, Phenological, SAR, Sentinel-1A.

INTRODUCTION

Cotton is the most important fiber and cash crop grown during the kharif season in Haryana state. It is also providing the basic raw material to the cotton textile industry. India is the second largest producer of cotton in the world while has the largest area under cultivation. In the kharif season the cloud cover restricts the operational use of the optical sensors especially in the cotton growing season (June-September). The optical sensor operates in shorter wavelength covering the short-wave infrared (SWIR), near wave infrared (NIR), red and green bands of electromagnetic spectrum. These shorter wavelength waves cannot penetrate through the clouds and light rain. So, optical data is not frequently available during the monsoon season (July to September) which is the main growing season of cotton crop. The SAR system being an active system operates in the microwave region of electromagnetic spectrum having the wavelength ranging from 1mm to 1m. These microwaves having longer wavelength can easily penetrate through the clouds and light rain. The SAR systems can offer the all weather data during the kharif season for the monitoring and identification of cotton crop. So the multi-temporal SAR data can be frequently acquired covering the all phonological stages of the cotton crop which may be very helpful for crop discrimination and identification.

Previous study performed the use of multi-temporal SAR data that can be very useful for monitoring and identification of crops and classify the agriculture lands (Oyoshi K *et al*, 2016; Chakraborty M *et al.*, 1997). Many experts have also generated radar signatures of cotton and other crops using SAR data (Dave R *et al.*, 2019 and Patnaik C *et al.*, 2005) and some authors have described the ability of SAR data for crop monitoring due to variations in backscatter characteristics during varied stages of crops (Torbick N *et al.*, 2017; Chakraborty M *et al.*, 1997).

This study demonstrates the potential of VV polarized multi-temporal Sentinel-1A, SAR data for monitoring the cotton crop during its growing period and temporal radar backscatter values of cotton and other associated major kharif season crops were analyzed. It is observed that changes in crop biomass, crop structure, dielectric properties associated with varies phonological stages causes the variation in the temporal radar backscatter values which is helpful for the crop identification and discrimination.

MATERIALS AND METHODS

Study Area

Sirsa district was carved out of Hisar district in 1975 and its ancient name was Sairishaka and from that it seems to have been changed to Sirsa. The Sirsa district lies in the extreme west corner of Haryana State and lies between 29º14' to 30º0' N latitudes and 74º29' to 75º18'E longitudes covering an area of 4277 sq. km. The average annual rainfall in the district is 222.72 mm and over 83% of it is received during the months of June to September. Partially it is also received during the winter months of December to February due to western disturbances. Wheat, mustard and gram are the main rabi season crops and rice, cotton and bajra are the main kharif season crops. The location map of the study area is shown in Figure 1.

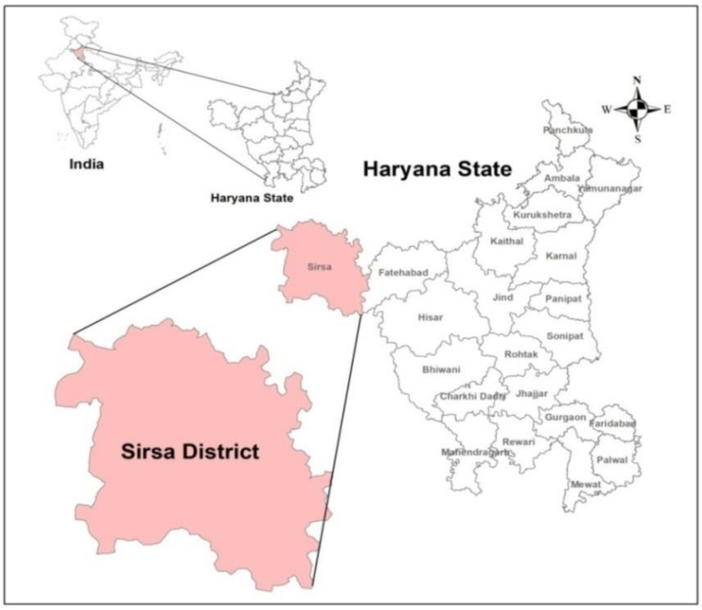

Figure 1: Location Map of Study Area

Data Used

Sentinel-1A multi-temporal SAR data used for the cotton crop monitoring and identification in the study area. For this purpose, multi-temporal Sentinel-1A C-band SAR data for the crop season May to September were downloaded from ESA's Copernicus website. In this study high resolution Level-1 Interferometric Wide Swath (IW) mode, Ground Range Detected (GRD) product type and Descending order VV polarized multi-date dataset have been used. The detailed specifications of Sentinel-1A and the details of multi-temporal images acquired for the analysis is given in table 1 & 2. The ground truth was collected by the state agriculture department officials using a Smartphone-based Android App, called Bhuvan FASAL, developed by "National Remote Sensing Centre" (NRSC), ISRO. The ground truth data includes location in the form of latitude and longitude, field photographs and field parameters which are uploaded to Bhuvan Portal. This data used to generate the RSS of crops and settlements in the district after downloading from Bhuvan portal.

Table 1: Specifications of Sentinel-1 data

Attribute	Value
Frequency	5.405 GHz
Polarization	HH/VV/HV/VH/HH+HV/VV+VH
Mode	SM/IW/EW/WV
Product Type	SLC/GRD/OCN
Resolution	20*20
Ground Range	250 km
Repetivity	12 days
Order By	Descending/Ascending

Table 2: Details of multi-temporal dates acquired for analysis

Sr. No.	Acquisition Date (2019)
1	15 May, 2019
2	08 June,2019
3	02 July,2019
4	26 July,2019
5	31 August,2019
6	12 September,2019
7	24 September,2019

METHODOLOGY

The SAR multi-temporal data from May to September as shown above was downloaded and preprocessed by following the standard procedure of apply orbit file, calibration, multilooking, speckle filtering and terrain correction. The multi-temporal preprocessed images were then co- registered, and a data stack was formed covering all the acquisitions. Using GT points temporal radar backscatter values were noted for the cotton, other associated kharif season crops and settlements from multi-temporal stack layers. Each crop has different date of sowing and growing pattern also having difference in crop biomass, moisture content, plant height, plant density per meter square. Due to this a significant difference in radar backscatter values for the different crops in multi-temporal SAR data was observed during their growing period. The details of methodology are shown in Figure 2.

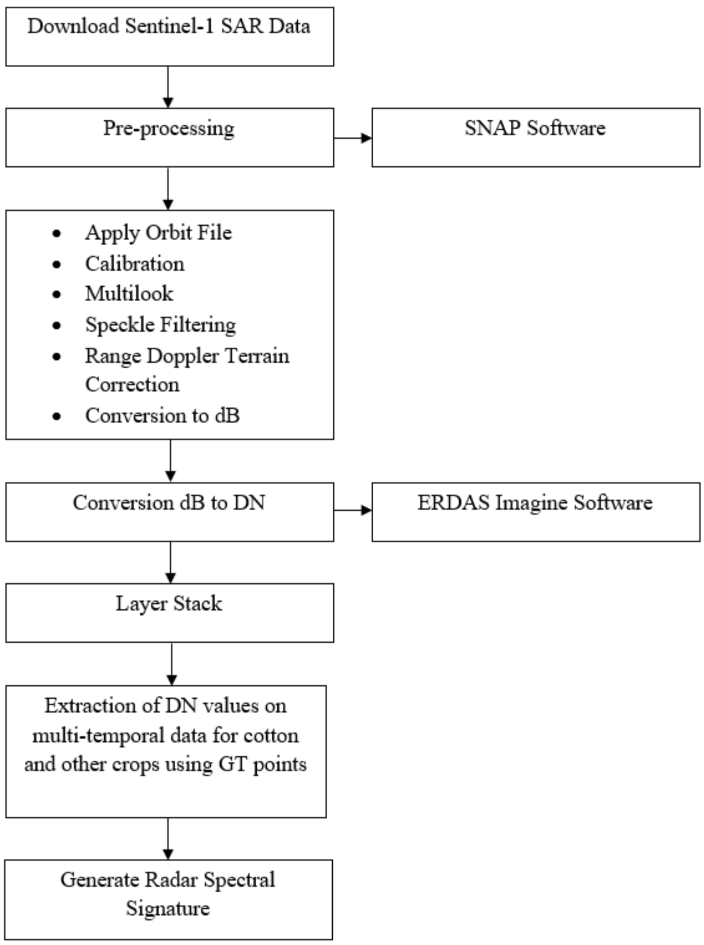

Figure 2: Methodology flow chart

RESULTS AND DISCUSSION

SAR Signature Study and Analysis

SAR backscatter from the crops depends on various crop biophysical parameters and soil parameters during its various growth and phenological stages. The increase in radar backscattering with change in crop structure and crop biomass due to the effect of volume scattering have been reported by many authors (Shang J *et al*, 2020**;** Kumari M *et al*, 2019; Nasirzadehdizaji R *et al*, 2019 and Khabbazan S *et al*, 2019). In case of cotton crop land preparation for showing, crop vegetative and boll formation are the main stages which directly affect the radar backscattering. In the present study radar backscatter response of other associated kharif season crop like paddy and other crops on multi-temporal SAR data was also examined for identification.

It is observed that the build-up areas have high backscatter in all the dates thus appearing very bright in the radar imagery. These areas can be clearly delineated in SAR images. The high backscattering from urban areas may be due to the corner reflectance or double bounce effect. In case of corner reflectance the two surfaces are mutually right angled to each other. In this case most of the radar energy is returned back to the receiver after bouncing twice thus the surface having very bright signature in the SAR imagery. Examples of such targets are urban areas and villages etc. So built-up areas have appearing as very bright patches in all the SAR images.

Temporal backscatter (DN) values of settlements is depicted in figure 3 which shows that very high radar backscatter is observed in all the dates (May to September) and very small change is observed in all the dates.

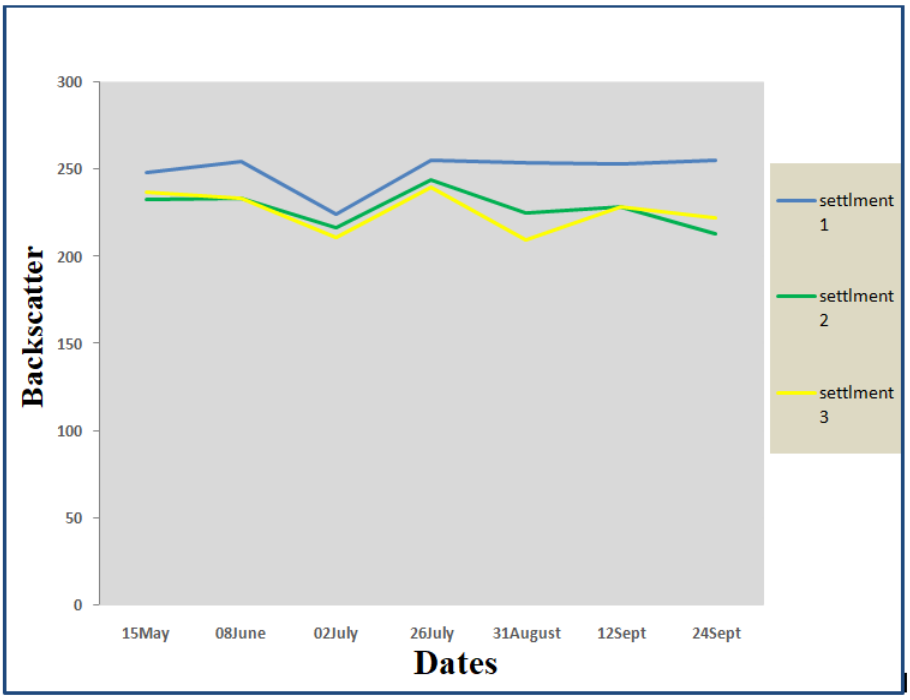

Figure 3: Temporal backscatter (DN) values of settlements

In the study area the paddy crop has sowing period starting from mid-June up to last week of July. The paddy crop requires a lot of water thus paddy fields are flooded with water at the time of transplanting of crop. As the paddy is transplanted on the flooded water so, very low backscattering is observed from the transplanted paddy fields in June and July. This may be due to the specular reflectance. The specular reflectance occurs from the flat surface like smooth playground and flooded water etc. In this case most of the radar energy is reflected away from the sensor resulting in low backscattering. As the paddy crop grows and attains its vegetative stage the canopy cover, crop biomass and leaf area increases. This results in presence of multiple scatters within the crop. This will change the scattering behavior and intensity of energy returned back to the SAR antenna. The backscattering increases due to double bounce and volume scattering from the crop as depicted in figure 4. In the September the backscattering gets saturated and after that no considerable increase in backscattering is observed. This may be as near the harvesting stage the moisture content within the crop is decreased resulting in reduced and saturated backscattering values. Many researchers have also generated radar signatures of paddy crop using SAR data (Kannan S *et al.*, 2021; Subbarao N *et al.*, 2020; Krishna A *et al.*, 2020; Jain V *et al.*, 2019 and Verma A *et al.*, 2019).

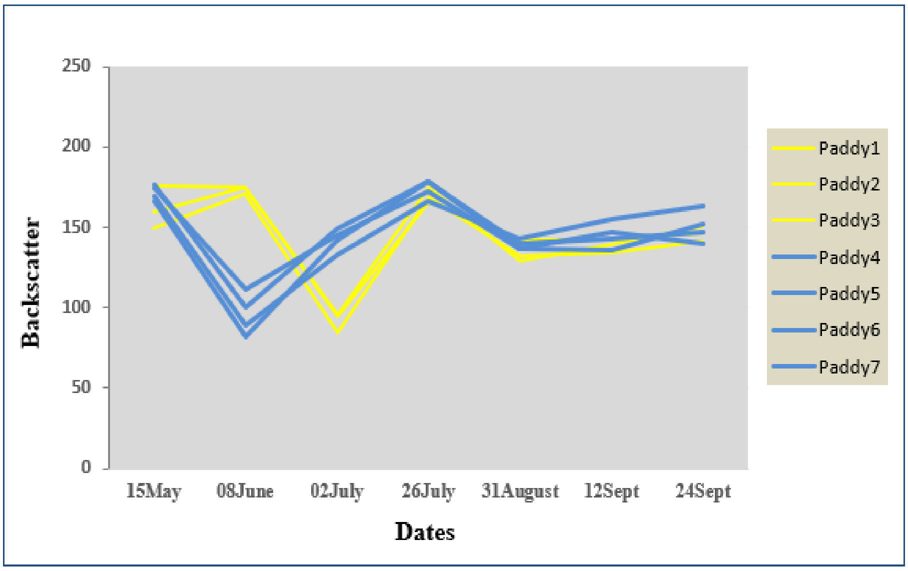

Figure 4: Temporal backscatter (DN) values of paddy crop

Temporal backscatter (DN) values for other crops (bajra, gwar etc.) are depicted in Figure 5. It is observed that for other crops high backscattering is observed in the month of June and July as compared to paddy crop. This high backscattering may be due to the roughness of the soil in the field. The results of many studies also indicate that roughness in the field results in high backscattering in SAR data. It is also observed that for other crops the decrease in radar backscatter is observed after the month of August. This may be due to the decrease in biomass and moisture content within the crop near to its harvesting stage. In September low backscattering is observed for the other crops as compared to cotton crop. The multi-date SAR backscatter values for other crops (bajra, gwar etc.) shows that the other crops can be clearly delineated from the cotton and paddy crops. So multi temporal VV polarized C-band SAR data is observed to be very useful for discriminating the other crops from the cotton and paddy crop.

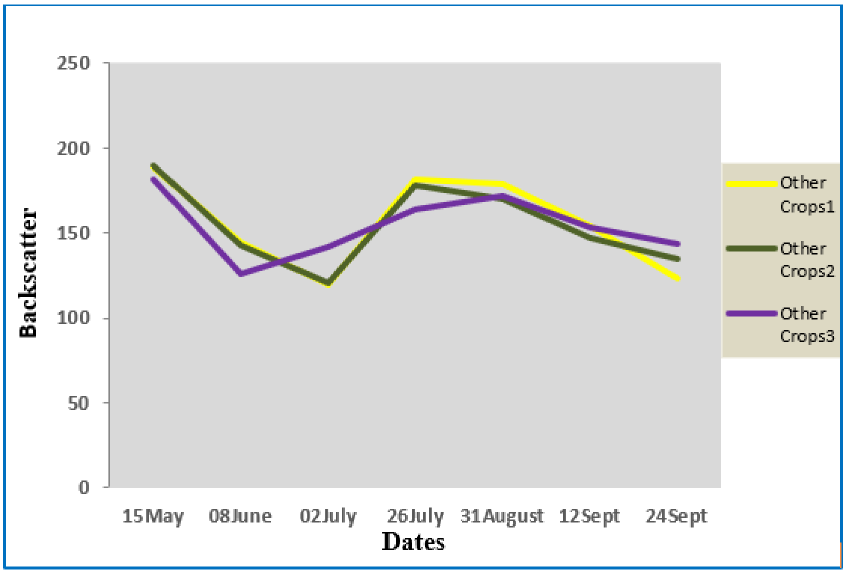

Figure 5: Temporal backscatter (DN) values of other crops

Cotton crop has sowing period starting from May to the first week of June. In the case of freshly sown cotton crop in May and June the backscattering mainly depends on the surface of soil. So, the fields having high moisture and medium to rough soil will give high backscattering. After July as the cotton crop grows radar backscattering further increases up to mid-September. This may be due to the fact that as crop grows the canopy cover, crop biomass and hence moisture content within the crop increases. So due to the presence of multiple scatters within the crop volume scattering of radar energy occurs when the SAR beam penetrates the crop. In volume scattering multiple bounces and reflection from the different components of the crop occurs thus resulting in high backscattering values. Depending upon the backscattering values in multi-temporal SAR data the cotton crop is further segregated in two categories i.e. late sown and early sown cotton crop. It is also observed that for late shown cotton crop there is an increase in radar backscattering from August to September shown in Figure 6. This may be due to an increase in the crop biomass and moisture content within the crop during this period. The result of many studies also shows that as the plant grows the SAR backscattering is also increased due to volume scattering (Dave R *et al.*, 2019; Ashmitha *et al.*, 2019 and Haldar D *et al.*, 2011). In comparison for early shown cotton crop the decrease in backscatter is observed after mid of September. This may be as after attaining peak vegetative stage (in mid of September) the plant biomass and hence moisture content within the crop starts reducing resulting in decreased backscatter (DN) values.

However, it is observed that for cotton Crop (early or late sown) high backscattering (DN) value is observed in September as compared to paddy and other associated kharif season crops as depicted in Figure 7. So, the multi-temporal SAR backscatter for cotton shows that the cotton crop can be clearly delineated from the paddy and other associated kharif season crops.

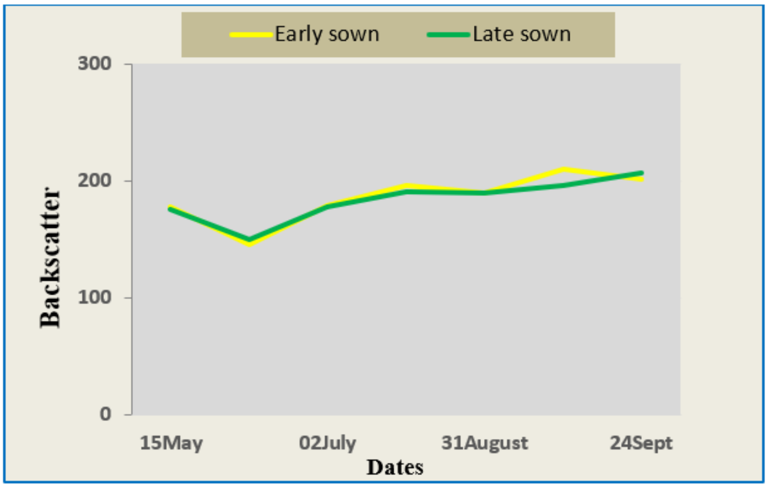

Figure 6: Temporal backscatter (DN) values of cotton crop

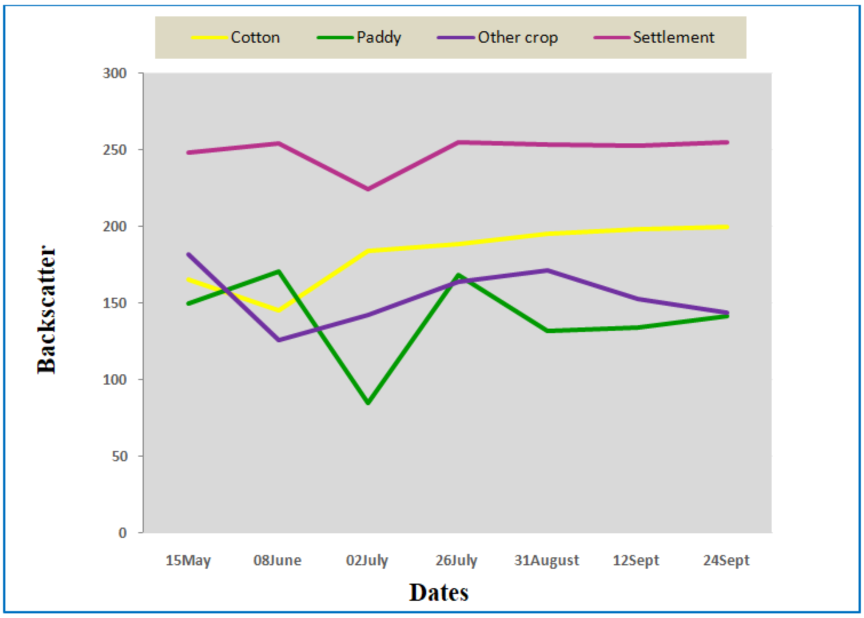

Figure 7: Temporal backscatter (DN) values of cotton, paddy, other crops and settlements

CONCLUSION

This study demonstrates the potential of VV polarized multi-date Sentinel-1A, SAR data for monitoring the cotton crop during its growing period. In the study temporal radar backscatter values of cotton and other associated major kharif season crops were analyzed. It is observed that changes in crop biomass, crop structure, dielectric properties associated with varies phonological stages causes the variation in the temporal radar backscatter values which is helpful for the crop monitoring and identification. The results of the study demonstrate the potential of multi-date Sentinel-1A SAR data for monitoring and identification of cotton crop with associated other kharif season crops.

ACKNOWLEDGEMENTS

The authors sincerely thank Director, NRSC for providing the necessary support for carrying out the present study. The authors sincerely thank Director, HARSAC, Hisar for their constant encouragement and valuable suggestions.

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Citation: Poonam Sharma *et al* (2021). Monitoring and Identification of Cotton Crop in Sirsa District Using Radar Spectral Signature. *South Asian Res J Agri Fish, 3*(5), 74-80.