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Review Article
The J. Res. PJTSAU 49(4) 1-11, 2021

# GLOBAL STATUS OF *THRIPS PARVISPINUS* (KARNY, 1922), AN INVASIVE PEST

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## ABSTRACT

Thrips are important group of sucking pests which cause significant economic losses both as pests and vectors of serious plant viruses in several horticultural crops. Recently an outbreak of *Thrips parvispinus* has been reported from southern states of India (Andhra Pradesh, Karnataka and Telangana) especially on chilli crop causing 70-100 per cent damage. *T. parvispinus*, a member of "*Thrips orientalis* group", is a widespread pest species of quarantine importance and designated as one of the pest species of South East Asia. *T. parvispinus* has displaced *T. palmi* in Indonesia indicating its competitive ability in displacement of other species in the crop ecosystem. Successful quarantine interceptions made throughout the world against this pest shows the importance of interceptions in avoiding the entry of invasive pests in to any country. Despite existence of the quarantine provisions, recent invasion of various exotic pests like South American tomato moth, rugose spiralling white fly, fall armyworm *etc*. into India in quick succession is a concern particularly under globalisation situation. Considering the seriousness of the damage caused by the invasive pest in India in the recent past, an attempt was made in this review to present the status of *T. parvispinus* at national and global level including its identification, taxonomic status, host range, development and biology, extent of damage and various management strategies. Importance of various IPM tools to be explored for the management of this invasive thrips is also discussed in the review.

**Keywords:** Chilli, invasive, *parvispinus,* polyphagous, thrips

Thrips are important group of sucking pests which cause significant economic losses both as pests and vectors of serious plant viruses in several horticultural crops. There are reports on the outbreak of sucking pests like thrips in different regions due to changes in crop production patterns, pesticide usage and climate change. Recenty an outbreak of *Thrips parvispinus* has been reported from southern states (Andhra Pradesh, Karnataka and Telangana) especially on chilli crop causing 70-100 per cent damage. Considering the seriousness of the damage caused by the invasive pest, an attempt is made in this paper, to present the status of *T. parvispinus* at national and global level including its identification, host range, extent of damage and management strategies.

The genus Thrips is one of the largest genera of the insect order Thysanoptera in the family Thripidae, with 295 species worldwide, of which 44 species are reported from India (Rachana and Varatharajan, 2017; Rachana *et al.*, 2018). Species of this genus are important pests causing damage directly by feeding and egg laying or indirectly by vectoring different pathogenic tospoviruses on economically important crops (Marullo and Mound, 2002). They cause damage by piercing and sucking the sap from different parts of the plant by their well-developed left mandible. The gravid females oviposit the eggs in to the plant tissues with the help of saw-like ovipositor (Ananthakrishnan, 1984). Their role as pollinators has also been documented on various tropical and subtropical crops (Varatharajan *et al.,* 2016). As insect vectors, thrips are sole transmitters of Tospoviruses (genus Tospovirus, family Bunyaviridae) affecting a number of plant species belonging to unrelated plant families across the globe (Riley *et al.,* 2011).

### 1.1. About *T. parvispinus*

*T. parvispinus*, a member of "*Thrips orientalis* group" (Mound, 2005), is a widespread pest species of quarantine importance and designated as one of the pest species of South East Asia. *T. parvispinus* has been documented from Thailand to Australia (Mound and Collins, 2000). It is reported on papaya in Hawaii, *Gardenia* sp. in Greece, vegetable crops like Capsicum, green beans, potato, and brinjal from other countries (Murai *et al.,* 2009). Occurrence of this

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species in India has been first reported by Tyagi *et al.,* (2015) on papaya from Bangalore. Present status of *T. parvispinus* globally is discussed in this review.

**2. Taxonomic Identity of** *T. Parvispinus*

**Species**

***Thrips parvispinus*** (Karny, 1922)

**Taxonomic history**

*Thrips* (*Isoneurothrips*) *taiwanus* Takahashi, 1936

*Isoneurothrips pallipes* Moulton, 1928

*Isoneurothrips jenseni* Karny, 1925

*Isoneurothrips parvispinus* Karny, 1922

**Common name (s)**

Taiwanese thrips, South East Asian Thrips, Tobacco thrips (?)

**Present taxonomic position**

Family: Thripidae Stephens, 1829

Subfamily: Thripinae (Stephens) Karny, 1921

Genus: *Thrips* Linneaeus, 1758

**3. Identification**

Females and males differ in size and colour. Females are nearly 1 mm long, with brown head and prothorax, yellowish brown meso- and metathorax and black abdomen; forewings are dark, with light coloured base; the third antennal segment and the base of the fourth and fifth segments are light coloured (either yellow or white). Males are 0.6 mm long and evenly yellow.

The following features segregate *T. parvispinus* from other known species of the genus Thrips.

a. Ocellar pair III at the anterior margin of ocellar triangle; postocular setae III shorter than postocular setae I and IV.

b. Metanotum reticulate medially; median setae long and placed well behind the anterior margin; campaniform sensilla absent.

c. First and second vein of forewing with continuous row of setae (Figures 1-3).

d. Posterior margin of tergite VIII without comb.

e. Abdominal sternites III-VI with discal setae, but absent on II and VII (Mound, 2005; Tyagi *et al.,* 2015; Mound *et al.,* 2016, Rachana *et al.,* 2018).

**3.1. Taxonomic Description of the species**

(Source: Factsheet - *Thrips parvispinus* http://thripsnet.zoologie.uni-halle.de/key-server-neu/data/0a0b0a0e-0d03-4106-8306-08060a080902/ media/Html/ Thrips%20 parvispinus.html)

Typical key character states of *Thrips parvispinus* are

**Coloration and body sculpture**

i. Body color: mainly brown to dark brown

Surface of head, pronotum: with transverse sculpture

ii. Legs: yellow

**3.1.1. Antennae**

Number of antennal segments: 7

Antennal segment I: without any setae on dorsal apical margin

Antennal segment III: yellow

Length of antennal segment III and IV: antennal segment III similar in length to segment IV

Form of sense cones on antennal segments III and IV: emergent and forked on segments III and IV

**3.1.2. Head**

Distance between bases of ocellar setae III: greater than width of first ocellus

Head: not prolonged in front of compound eyes

Ocellar setae I: absent

Length of ocellar setae II: shorter than setae III

Ocellar setae III: arising on anterior margin of, or in front of ocellar triangle

Number of ocellar setae: 2 pairs

**3.1.3. Prothorax**

Number of pairs of long posteroangular setae: 2

Number of pairs of posteromarginal minor setae: 3-4

**3.1.4. Metathorax**

Metanotalcampaniformsensilla: absent

Reticulations of metanotal sculpture: prominent median reticulated sculpture

Metanotal median setae: S1 behind anterior margi

**3.1.5. Wings**

Fore wing veins: present

Fore - and hind wing surface: covered with microtrichia

Fore and hind wings: present, more than half as long as abdomen (macropterous)

Apex of fore wing: with prominent terminal setae

Fore wing anterior margin (costal vein): with setae and cilia but cilia longer than setae

Fore wing clavus - number of marginal setae: 5

Fore wing clavus - terminal veinal seta: longer than subterminal seta

Fore wing costal fringe cilia: arising at anterior margin of wing

Fore wing first vein: distinct from costal vein

Fore wing first vein setal row: complete, with setae closely and uniformly spaced

Fore wing second vein setal row: complete, setae uniformly spaced

Fore wing shape: mainly parallel sided or margins run continuously towards each other

Fringe cilia on posterior margin near apex: distinctly wavy (undulated)

Shape of fore wing apex: with mainly posterior margin curved to join anterior margin

Fore wing extreme apex color: dark

Fore wings: uniformly dark or shaded, but with base or sub-base pale

### 3.1.6. Legs

Mid and hind tarsi: with two segments

Color of fore tarsi: pale or yellow, sometimes apical shaded or brown

### 3.1.7. Abdomen

Pleurotergaldiscal setae: absent

Sternite II: with marginal setae but no discal setae

Number of discal setae on sternites III to VI: 6-12 (13)

Sternites IV, V and VI: with marginal setae and discal setae medially

Pairs of posteromarginal setae on sternites V and VI: 3

Sternite VII median posteromarginal setae S1: arising in front of posterior margin

Sternite VII: with marginal setae but no discal setae

Number of lateral marginal setae on tergite II: 4

Sculpture of tergites II to VIII: with one or without transverse lines of sculpture between median pair of setae S1

Tergites II to VII median setal pair: no more than 0.3 as long as median length of tergite

Craspedum on tergites IV to VI: absent

Tergites IV and V median setal pair: shorter than distance between their bases

Markings on tergites IV to VI: without shaded areas medially

Tergites V to VII: with ctenidia laterally

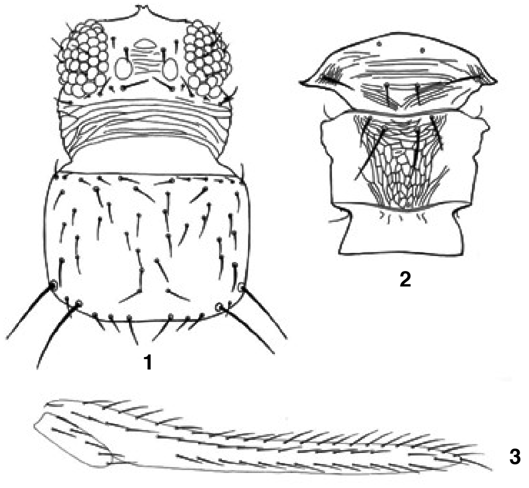
Craspedum on tergite VIII: without craspedum medially and toothlike microtrichia laterally

Tergite VIII ctenidia: posteromedial to spiracle

Color of tergites IX and X: dark or brown

Tergite X: not tubular, longitudinally incomplete

Setae on abdominal tergite X: all setae slender




***Figures 1-3.* *T. parvispinus*, female**
**(1) head and pronotum; (2) meso-andmetanotum, (3) fore wing** **Source:** Tyagi *et al.,* (2015)

### 4. Similar or related species to *T. parvispinus*

Species of the Genus Thrips (Thysanoptera, Thripidae) from the Afro-tropical region were described and identification keys were given by Mound (2010). *T. parvispinus* is very similar to other *Thrips* species - like *Thrips orientalis*. *Thrips parvispinus* has discal setae on sternites III-VI but not on sternite VII, and no discal setae on pleurotergites (*Thrips australis*, *Thrips microchaetus*, *Thrips subnudula* and *Thrips tenellus*, all of them have sternites III-VII with at least 1 pair of discal setae and pleurotergites with discal setae; *Thrips acaciae*, *Thrips brevisetosus*, *Thrips florum, Thrips gowdeyi*, *Thrips hawaiiensis* and *Thrips simplex*, all of them have sternites III-VII with at least 1 pair of discal setae and pleurotergites without discal setae; *Thrips nigropilosus*, *Thrips palmi*, *Thrips pusillus* and *Thrips tabaci*, all of them have sternites and pleurotergites without discal setae).

*Thrips parvispinus* differs from *Thrips orientalis* in having sternites III-VI with 6-13 discal setae in an irregular row, metanotal equiangular reticulations rarely with faint internal sculptured markings, brown fore wings with base sharply paler, on fore wing clavus the terminal veinal seta is longer than subterminal seta, and the fore wing first vein setal row is complete. *Thrips orientalis* has sternites III-VI with no more than 6 discal setae placed laterally, metanotal equiangular reticulations with many conspicuous internal sculptured markings, brown fore wings only with small white spot near veinal fork, on fore wing clavus the terminal veinal seta is shorter than subterminal seta, and the fore wing first vein is highly variable on distal half, from almost complete to only 2 setae medially and 4 distally. Outside this group, the species is similar to *Thrips australis* in having a metanotal median sculpture with mainly equiangular reticulation, the fore wing first vein with setal row complete, and the comb of tergite VIII is present laterally and absent medially.

## 5. Hosts and Damage

### 5.1. Hosts

*Thrips parvispinus* is a polyphagous pest with a wide range of hosts varying across its geographic distribution (Table 1). It is a pest mainly on fruit, vegetable and ornamental crops, such as coffee, *Gardenia* sp., papaya, chilli pepper, sweet pepper, potato, tobacco, *Vigna* sp., green bean, strawberry, shallots, watermelon and other cucurbits (EPPO, 2001; Azidah, 2011; Hutasoit *et al.,* 2017; Moritz *et al.,* 2013; for an extensive list see Sartiami and Mound, 2013). It is reported on papaya in Hawaii, *Gardenia* sp. in Greece, vegetable crops like Capsicum, green beans, potato, and brinjal from other countries (Murai *et al.,* 2009). In Europe it is found on ornamentals in green houses, Citrus, *Dipladenia*, *Ficus benjamina*, Gardenia, Gerbera and Schefflera (Lacasa *et al.,* 2019). In regions where the species has been long established, the crops most affected are papaya, peppers, potatoes, egg plants, beans, shallots, crotalaria, *Vigna* sp., coffee, cucumber, tobacco (Hutasoit *et al.,* 2017). It is most damaging to papaya

**Table 1. Host range of *T. parvispinus* across the world**

| Hosts Reported | Reference |
|---|---|
| Black Jack (*Bidens pilosa*), coffee, *Gardenia* sp., papaya, chilli pepper, paprika, potato, tobacco, *Vigna* sp., green bean, strawberry, egg-plant, watermelon and other cucurbitaceae | (Factsheet - *Thrips parvispinus* (uni-halle.de)) |
| Papaya | Tyagi *et al.,* 2015 |
| Papaya, peppers, potatoes, eggplants, beans, shallots, crotalaria, vigna, coffee, cucumber, tobacco | Hutasoit *et al.,* 2017 |
| Anthurium, chrysanthemum, dahlia, dipladenia, gardenia and ficus | NPPO, 2019 |
| Chilli, weed species like Parthenium, *Amaranthus* sp., *Axonopus* sp., *Ageratum* sp. *Alternanthera* sp. *Thunbergia* sp, foliage of neem and pongamia | Nagaraju *et al.,* 2021 |
| Pepper, anthurium and hoya | Johari *et al.,* 2014 |
| Chilli, capsicum, mango, cotton, drumstick, cucumber, bottle gourd, bitter gourd, beans, marigold, chrysanthemum, watermelon, coccinea, brinjal *etc.* | Sridhar *et al.,* 2021 (In press) |

in Hawaii and Indonesia, peppers and other solanaceous crops in Indonesia and ornamentals in Europe and Indonesia. Also reported as a pest from India on papaya plantations (Tyagi *et al.,* 2015). Ornamental plant *Dahlia rosea* Cav. has been reported as new host for the quarantine thrips, *T. parvispinus* from Karnataka, India (Rachana *et al.*, 2018)

**5.2. Damage**

The damage symptoms include deep punctures and scratches on under- side of the leaves, due to sucking of sap. Underside of the leaf turns reddish brown and upper side of the leaf looks yellowish. Distorted leaf lamina has necrotic areas and yellow streaking. On floral parts, scraping on petals is observed resulting in brownish streaks on petals. Drying and withering of flower affected fruit set. Growth of the plant also will be affective as it feeds on growing portions of the plant. Significant flower drop is also observed in severely infested fields. Several adults, both male and female were observed feeding and hiding in the base of the chilli flowers (Plate 1) (Sireesha *et al.,* 2021).

**Plate 1. Female (black and large) and Male (yellowish and small) adults of *T. parvispinus* feeding on chilli flowers**

*T. parvispinus* is a dangerous insect pest that attack and damage chilli plants. These pests damage plants by sucking and whittling. The damage, which was caused by thrips in Bandung and Bogor Regency of Indonesia ranged 10-46% (Johari *et al.*, 2014). Major damage is caused by direct feeding of larvae and adults on leaves and growing buds, but at least in papaya, tissue damaged by the thrips may be secondarily and independently infected by a saprophytic fungus, *Cladosporium* (Lim, 1989). It also damaged ornamentals such as Dahlia, Chrysanthemum, Gardenia, Dipladenia and Ficus. In Florida, *T. parvispinus* was found only on Anthurium and Hoya growing in greenhouses. Damage to Anthurium was most evident on leaves. Varieties Cyrano, Charade White, Zizou and Sierra White are most susceptible to attack. In Hoya, thrips attack eventually kill the buds.

**5.3. Vector capacity**

Tobacco streak virus (TSV), mechanical transmission of *Cladosporium oxysporum* causing bunchy-top, *i.e.* malformed leaves and shot holes on new flushes (Lim, 1989). However, *Thrips parvispinus* is not known to transmit tospoviruses.

**6. Development and Biology**

Female insert eggs into leaves. After four to five days, larvae hatch and feed on leaves and flowers. Larvae go through two molts in four to five days, mature and pupate. The two pupal stages last two to three days. Reproduction is sexual and on an average females lays 15 eggs. Mated females live nine days. Adult males live six days (Hutasoit *et al*. 2017). Total life cycle of *T. parvispinus* is completed in 13 - 14 days.

According to the biological and demographic information recorded by the Hutasoit *et al.* (2017), there are five phases of immature stages of *T. parvispinus, i.e.,* eggs, two nymphal instars, prepupa, and pupa with their stadia 4.79, 1.36, 3.54, 1.08 and 1.96 days respectively. The preoviposition period of the insect was 1.11 days, life cycle was 13.68 days, female longevity was 8.55 days, male longevity was 6.00 days, and fecundity was 15.33 eggs per female. The population development of *T. parvispinus* followed type III of survivorship curve with intrinsic rate of increase of 0.15 individuals per day per female, net reproductive rate was 5.71 individual per female per generation with generation time of 11.49 days and doubling time was 4.57 days. The average developmental period of the pre-adult phase or the stage of becoming imago of *T. parvispinus* lasted for 12.97 and 12.57 days in males and females, respectively. It was also observed that *T. parvispinus* has metamorphosis transition between paurometabola and holometabola (Borror *et al*., 2005). Murai *et al.* (2010) observed mean fecundity and mean generation time at 20°, 25° and 30°C were 50, 69, and 56 eggs and 37.6, 24.8 and 18.8 days, respectively. Intrinsic rate of natural increase at 20°, 25° and 30°C was 0.18, 0.24 and 0.37, respectively.

**7. Establishment and Distribution**

*T. parvispinus* is known from Thailand and Malaya to New Guinea and northern Australia, also Hawaii, Micronesian Islands, and Greece. It has widespread in Southeast Asia to northern Australia and Solomon Islands (Palmer, 1992), extending its area of distribution to the north (Yunnan – China) (Zhang *et al*., 2011), the Philippines (Reyes, 1994) and Taiwan (Mound and Masumoto, 2005) and India (Tyagi *et al*., 2015; Rachana *et al*., 2018). It has been reported from Hawaii in 2006 (Sugano *et al.,* 2013). In Africa, it has been recorded from the French overseas department La Reunion (Bournier, 2000), from Mauritius (Mound, 2010) and from the mainland in Tanzania (Dar-el-Salaam) and Uganda (Kampala) (Moritz *et al*., 2013). In Europe, it has been reported from Greece in 1998 (Mound and Collins, 2000), Spain in 2017 (Lacasa *et al.,* 2019) and from France in 2018 (EFSA, 2019).

Sartiami *et al.* (2011) had recorded the information regarding the morphological diversity of *T. parvispinus* at three different altitudes which include Cirebon (< 30 m asl), Bogor (300 - 400 m asl), and Cianjur (> 1200 m asl). It was revealed that the body length, thoracic width, and wing length of the highland thrips were longer than those of the mid and lowland thrips. Changes in the color of head was also observed, dominant color for the area Cianjur was dark brown (chocolate dark) on the head, olive brown (olive green chocolate) and dark brown (dark brown) for the thorax, and dark brown for abdominal part. At lower level, *i.e*, Bogor and Cirebon, colors dominant for the head and thorax is olive brown while the abdomen is dark yellowish brown (dark yellowish brown) (Cirebon) and dark brown (dark brown) (Bogor).

In Europe factors affecting the establishment of T*. parvispinus* was studied. Based on the similarity in feeding biology to *Thrips tabaci* and in abiotic and biotic requirements to *Thrips palmi*; it was concluded that the species will probably be able to survive indoors in protected crops throughout the EU and possibly outdoors in some parts of Southern Europe. EFSA_Panel_on_Plant_Health (2019) concluded for *Thrips palmi* that "only a small area of the EU provides climatic conditions where establishment may be possible outdoors". They further observed that this may also be the case for *T. parvispinus.*

**Spread of thrips:** Thysanoptera, including *Thrips parvispinus*, can especially be spread by trade/ movement of infested plants. No data are known about its ability to spread by natural dispersal (by flight, wind), but most likely this will be very similar to other thrips pests already present (i.e., they may disperse by wind over several hundreds of metres when temperatures are high; the probability of natural spread between glasshouses may be low especially in cooler areas and during cooler periods).

**Species replacement capabilities:** Sridhar *et al.* (2021) observed that in T. *parvispinus* outbreak areas in India, it has displaced the well-established chilli thrips, *Scirtothrips dorsalis* in chilli ecosystems from the states of Andhra Pradesh, Karnataka and Telangana. However, they opined that systematic monitoring is to be taken up to establish whether it is an ecological phenomenon of species displacement is of seasonal importance, whether it is reversable or irreversible. In Indonesia, *T. parvispinus* has replaced *Thrips palmi* as the key thrips on vegetables (Murai *et al.,* 2010).

**Interceptions of *T. parvispinus***

Interceptions have been reported on produce such as cut flowers and vegetables, indicating its potential to spread via trade. In the Netherlands *T. parvispinus* has been intercepted (as *T. taiwanus*) as early as 1996 on a consignment of Gardenia cut flowers from Indonesia and on shipments containing various cut flower species from Asia since then. Other European countries have intercepted *T. parvispinus* several times during the past 2 decades: - in the UK on Gardenia from Indonesia (Mound and Collins 2000) and on Orchidaceae from Malaysia (Collins, 2010), - in Switzerland on *Rosa* spp. from Thailand (January 2013) and on *Momordica charantia* from Sri Lanka in 2016 (Andreas von Felten, Swiss Plant Protection Service SPPS, pers. comm., 2019.) and on *Solanum aethiotipum* vegetables from Uganda (EPPO, 2016; EU, 2016) - in France it was intercepted on *Momordica charantia* vegetables from Cambodia (EPPO, 2014). In Japan it has been intercepted on *Heliconia* shipped from Mauritius. Although most interceptions have been made on cut flowers and vegetables, *T. parvispinus* has been intercepted on plants for planting in the Netherlands, on *Ixora* pot plants from Thailand in 2005, and on a Whrightia pot plant from Indonesia in 2013 (Quick scan *Thrips parvispinus*, 2019).

**8. Outbreak of *T. parvispinus* from India**

Outbreak of this species was reported from the states of Andhra Pradesh, Telangana and Karnataka during 2021 causing 70-100 per cent damage in severely infested fields (Plate 2). Thrips on chilli flowers were first noticed in Chilakaluripeta and Pratipadu mandals of Guntur district of Andhra Pradesh state, during January, 2021 and subsequently its spread was noticed in all chilli growing areas in the state (Sireesha *et al.,* 2021). The pest is also infesting the red chilli crop in districts of Telangana and Andhra Pradesh. The infestation occurs at flowering stage and affecting the fruit development. (https://www.thehindu business line.com/markets/commodities/pests-attack-chilli-crop-in-telangana-ap/article 37917372.ece). It also inflicts injury to ornamentals *viz*., Anthurium, Chrysanthemum, Dahlia, Dipladenia, Gardenia and Ficus (NPPO, 2019). Flowers of weeds species *viz.*, Parthenium, *Amaranthus* sp., *Axonopus* sp., *Ageratum* sp. *Alternanthera* sp. *Thunbergia* sp. found in chilli fields and foliage of neem and pongamia bordering chilli fields were also found infested with *T. parvispinus* (Nagaraju *et al.,* 2021). The invasion of *T. parvispinus* attained lag phase and resulted in its population increasing alarmingly within a short duration of four years, and that has influenced their adaptability on diverse plant hosts, in addition to their tendency to expand geographical range within the country (Rachana *et al.,* 2021).

**Plate 2. Team visiting the Severely infested fields of chilli due to *T. parvispinus* in Telangana state**

**9. Management**

Very limited information is available regarding management of *T. parvispinus* worldwide. The available information based on field studies conducted and some of the ad hoc recommendations made where the incidence is in severe proportions is presented here.

**9.1. Cultural measures**

- Removal and destruction of the severely infested plants to stop further spread
- Use of healthy and pest free seedlings for planting
- Constant systematic monitoring and inspection for its infestation in new areas through surveys in chilli growing areas
- Chilli pepper lines resistant to *Thrips parvispinus* have been identified. Six pepper accessions (*C. annuum* AC 1979, *C. annuum* Bisbas, *C. annuum* Keystone Resistant Giant, *C. annuum* CM 331, *C. baccatum* no. 1553, and *C. baccatum* Aji Blanco Christal) were identified as good sources for resistance against *T. parvispinus* and *F. occidentalis* (Maharijaya *et al*., 2011)
- Nitrogen and potash fertilizers can be applied in five splits during crop growth
  a. Organic fertilizers like FYM@10 tones/ acre
  b. Neemcake @200kg/acre
  c. Vermicompost @2tonnes/acre
  d. Azospirillum and phosphate solubilizing bacteria each @2kg/acre, in order to maintain proper nutrition to the plants
- Avoiding excessive use of nitrogenous fertilisers and application of recommended and balanced use of fertilizers needs to be followed (Sireesha *et al.,* 2021).

**9.2. Physical/ Mechanical measures**

- Murai *et al.* (2010), observed T. *parvispinus* was more attracted to white rather than blue or yellow colour traps. Others have observed Blue and yellow sticky traps attracting more *T. parvispinus* adults (Sireesha *et al.,* 2021)
- Laboratory studies indicated that they are susceptible to spinosad and not to acetamiprid (Murai *et al*., 2010). Exposure to 60% $CO_2$ atmospheres at 30°C results in 100% mortality

of five different thrips species, *Frankliniella occidentalis* (Pergande), *Frankliniella intonsa* (Trybom), *Thrips tabaci* Lindeman, *Thrips palmi* Karny, and *Thrips parvispinus* Karny (Seki and Murai, 2012)

**9.3. Botanicals**

- Application of neem cake @ 200 kg /acre even on the standing crop
- Use of neem oil, pongamia oil or soap solution in heavily infested sites. Judicious use of chemical insecticides as well as fertilizers as per the Package of Practices (POP) recommended by the local regions/Universities/Departments. (ICAR- NBAIR, Pest alert, 2021)

**9.4. Biological control**

- Research on natural enemies of thrips and a control threshold to support integrated pest management (IPM) of thrips (*T. parvispinus*) on sweet pepper in protected cultivation in tropical conditions in Indonesia was conducted in 2003 and 2005. Two species of ladybird beetles, *Menochilus sexmaculatus* and *Coccinella transversalis*, and an entomophagous fungus, *Lecanicillium lecanii* were identified as potential natural enemies. The use of *M. sexmaculatus* and *V. lecanii* suppressed plant damage due to thrips infestation and resulted in sweet pepper yields that were equal to yields where insecticides were routinely sprayed twice weekly. The implementation of thrips control thresholds suppressed the thrips population, maintained plant damage below 10%, and reduced the frequency of insecticide spraying by approximately 90%, and sustained sweet pepper yield (Prabaningrum *et al*., 2008)
- Microbial biopesticide based management practices- *Pseudomonas fluorescence*- NBAIRPFDWD @ 20 g/l or Bacillus albus - NBAIR-BATP @ 20 g/l spray focusing on flowers and fruits

**9.5. Chemical management**

Sugano *et al*. (2013) suggested to spray papaya with rotation of chemicals with different mode-of action classes to minimize pest resistance. Spray should be targeted at the flowers and growing shoot of the papaya plant, as *T. parvispinus* lives and feeds there. A surfactant such as Latron B-1956 should be used to improve the spreading and wetting of the leaves and thus provide better control as young papaya leaves and fruit tend to have waxy surfaces and can be hard to wet. Application of azadirachtin 10,000 ppm @ 1 ml/L before flowering either as single application or in combination with recommended chemicals after thorough mixing in order to manage the resistance development. Rotation of insecticides *viz.,* fipronil 80WG @ 40g/acre/ fipronil 40% + imidacloprid 40% @ 40 g/acre/ cyantraniliprole 10% @ 240ml/acre/ acetamiprid 20SP @ 40 g/acre/ spirotetramat 150 OD @ 160 ml/acre is being suggested as ad hoc recommendation for the management of outbreak of *T. parvispinus* (Sireesha *et al.,* 2021). Anitha Kumari *et al.,* (2021) also recommended on ad hoc basis spraying of fipronil 80% WG @ 0.2 g/lit or cyantraniliprole @ 1.25 ml/lit or acetamaprid @ 0.2 g / lit or spinosad @ 0.3 ml/lit water as sequential sprays at weekly interval to manage *T. parvispinus.*

## CONCLUSION

Regular monitoring of invasive thrips, *T. parvispinus* on different crops in chilli growing areas is essential to take up timely interventions and to contain its further spread. Being an invasive pest and highly polyphagous, bioecology studies helps in understanding the behaviour of the pest and in planning effective IPM. Community approach in pest management helps in better management of thrips particularly when the incidence is flaring up at large scale. As the pest is invasive, there is a need to develop baseline toxicology data regarding its susceptibility for different insecticides recommended for thrips management for planning Insecticide Resistance Management strategies, as a part of IPM. Under-standing the reasons for the outbreak of *T. parvispinus* under changing climatic conditions and other ecological and genetic factors helps in preparedness in case similar conditions happens in future. Overall, an integrated pest management approach for tackling *T. parvispinus* by including various eco-friendly tools *viz.*, host plant resistance, biological control options like entomopathogens, physical and mechanical control measures, use of eco-friendly insecticide molecules *etc.* are suggested followed for its effective management.

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# EFFICACY OF ORGANIC SOIL AMENDMENTS, FUNGICIDES AND CHITOSAN AGAINST *MACROPHOMINA PHASEOLINA* UNDER *IN VITRO* CONDITIONS

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## ABSTRACT

Among the diseases of maize, Charcoal rot (*Macrophomina phaseolina*) was found to be the most prevalent and destructive in nature especially in rainfed conditions. Complexity of the disease and its soil borne nature, made the charcoal rot very difficult to manage in field. In the present study, different organic soil amendments, fungicides and chitosan at various concentrations were evaluated for their efficacy in inhibiting mycelial growth of *Macrophomina phaseolina* under *in vitro* conditions by using poisoned food technique. Neem cake was found superior in inhibiting mycelial growth of *Macrophomina phaseolina* at all the concentration tested (5%-38.52%; 10%-58.34%; 20%-62.96%) and showed significantly highest mean mycelial inhibition (53.27%) followed by castor cake (5%-31.67%; 10%-53.52%; 20%-56.48%) with mean mycelial inhibition of 47.22%. Among the fungicides, carbendazim completely inhibited the mycelial growth of *Macrophomina phaseolina* at all concentrations tested (50 ppm -1000 ppm) followed by mancozeb and tebuconazole + trifloxystrobin which could able to completely inhibit the mycelial growth of the pathogen at 500 ppm and above only, with mean mycelial inhibition of 96.70% and 94.19% respectively. Chitosan could able to inhibit the mycelial growth of test pathogen at 2.5 mg $ml^{-1}$ concentration and above. In conclusion, effective organic soil amendment, fungicide and chitosan can become components for a viable integrated disease management strategy against *Macrophomina phaseolina*.

**Keywords:** Charcoal rot, chitosan, fungicides, invitro conditions, neem cake

Maize is the third most important crop of our country after rice and wheat. The total production of maize in India is 27.71 Mt from 9.02 Mha. Telangana occupies seventh position in India, in terms of cultivated area of 0.54 Mha and fifth position in production with 2.08 Mt (Indiastat, 2018-19).

Among the diseases of maize, Post flowering stalk rot (PFSR) complex is the most serious and destructive disease and is a major constraint in realizing its full yield potential. The disease causes internal de-cay and discoloration of stalk tissue, directly reducing yield by blocking translocation of water and nutrients resulting in death and lodging of the affected plant during the crop season.

Though different fungal pathogens are reported to be associated with PFSR complex of maize, Fusarium stalk rot (*Fusarium verticillioides*), Charcoal rot (*Macrophomina phaseolina*) and Late wilt (*Cephalosporium maydis*) are found to be the most prevalent and destructive in nature (Khokhar *et al.*, 2014). Of these, Charcoal rot was reported to be majorly responsible for increased yield losses especially in arid and semi arid regions, where moisture stress coincides with flowering stage of the crop, particularly in rainfed maize growing areas of Telangana, Karnataka and Tamil Nadu.

As the pathogen is soil-borne in nature it is difficult to manage charcoal rot under field conditions and there is no effective management practice operating against the disease. Under these circumstances, information generated through *in vitro* studies would serve as guide for further field studies.

Owing to the complexity of the disease, use of fungicides alone is not sufficient to manage the disease and an integrated approach needs to be developed. In this view, the present investigation was carried out to test various organic amendments, fungicides and chitosan at different concentrations under *in vitro* conditions to test their efficacy in inhibiting the mycelial growth of *M. phaseolina*.

## MATERIAL AND METHODS

All the experiments were carried out at Department of Plant Pathology, College of Agriculture, Rajendranagar, Hyderabad, India. Different organic soil amendments, fungicides and chitosan at various

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concentrations were evaluated against *Macrophomina phaseolina* under *in vitro* conditions by adopting poisoned food technique.

**A. Organic Soil Amendments**

Five organic soil amendments *viz.,* neem cake, castor cake, vermi compost, farm yard manure and groundnut cake were tested at 5%, 10% and 20% concentrations for their efficacy to inhibit the mycelial growth of *Macrophomina phaseolina* using standard protocol (Kumar *et al*., 2017).

**Preparation of standard extract solutions**

The organic soil amendments were first soaked separately in sterile distilled water at the rate of one gram per one milli litre of water for overnight period and ground in mortar and pestle, by adding sterile water at the ratio of 1:1. The macerate thus obtained was strained through two layers of muslin cloth and finally filtered through Whatman No. 1 filter paper to get the standard extract solution (100%). The solution was collected in 250 ml conical flasks and tightly wrapped with aluminium foil and autoclaved at 121°C temperature and 15*psi* pressure for 15 minutes. The autoclaved extracts were individually added to conical flasks containing previously sterilized molten potato dextrose agar medium @ 5%, 10% and 20% concentrations just before pouring the medium into petri plates, mixed well in laminar air flow chamber, then poured into sterilized petri plates and allowed to solidify. Mycelial discs (5mm) from actively growing 5 days old pure culture of *M. phaseolina* were placed in the centre of solidified medium and were incubated at 28±2°C temperature. Three repetitions were maintained for each treatment under completely randomized design (CRD) and the plates with unamended medium served as control.

Radial growth of the colony in the treatments was measured when the mycelial growth in control plate was full and the per cent growth inhibition of the pathogen was determined by using following formula.

I = (C-T/C) x100

I = Per cent growth inhibition

C = Radial growth of pathogen in control (mm)

T = Radial growth of pathogen in treatment (mm)

**B. Fungicides**

Eight fungicides *viz.,* mancozeb 75% WP (Indofil M-45), carbendazim 50% WP (Bavistin), tebuconazole 250 EC (Folicur), propiconazole 25% EC (Tilt), carboxin 37.5% + thiram 37.5% (Vitavax power), azoxystrobin 20% + difenoconazole 12.5% SC (Amistar top), azoxystrobin 11% + tebuconazole 18.3% SC (Custodia) and tebuconazole 50% + trifloxystrobin 25% WG (Nativo) were tested for their efficacy to inhibit mycelial growth of the *Macrophomina phaseolina* under *in vitro* by poisoned food technique (Chaudhary *et al.,* 2017).

Fungicides were amended in autoclaved PDA at requisite quantity to obtain the concentrations of 50, 100, 250, 500 and 1000 ppm under aseptic conditions in laminar air flow chamber. Flasks containing poisoned medium were shaken well to have even and uniform distribution of fungicides. Measured quantity of (20-25 ml) amended PDA medium was poured into sterilized petri plates (9 cm dia.) and was allowed to solidify. Plates containing PDA without any fungicide were maintained as untreated controls. Each petri dish was inoculated with a 5 mm disc cut from the margins of actively growing 5 days old pure culture of *M. phaseolina*. Each treatment was replicated three times under completely randomized design (CRD) and incubated at 28 ± 2°C. The radial growth of colony in fungicide amended plates was measured when the mycelial growth in control plate was full. Per cent mycelial inhibition was determined using the formula mentioned above.

**C. Chitosan**

The inhibitory effect of chitosan on the mycelial growth of *Macrophomina phaseolina* was evaluated at different concentrations on PDA medium by poisoned food technique.

**Preparation of stock solution for chitosan**

To prepare chitosan stock solution (10 mg $ml^1$), 2 g of high molecular weight chitosan was dissolved in 100 ml of distilled water with 2 ml of acetic acid (stirred for 24 h), and the volume was made upto 200 ml with distilled water. Chitosan solution was autoclaved at $121^0$C temperature and 15 *psi* pressure for 15 min. The stock solution was further used to obtain desired concentrations by adding to PDA medium (Jabnoun-Khiareddine *et al*., 2016).

**Antifungal activity of chitosan against *Macrophomina phaseolina* under *in vitro* condition**

Chitosan stock solution (10 mg $ml^{-1}$) was amended in autoclaved PDA at requisite quantity to obtain the concentrations of 0.5, 1.0, 1.5, 2.0, 2.5 and 3 mg $ml^{-1}$ under aseptic conditions in laminar air flow chamber. Flasks containing poisoned medium were shaken well to have even and uniform distribution of the chitosan solution. Measured quantity of (20-25 ml) amended PDA medium was poured into sterilized petri plates (9 cm dia.) and was allowed to solidify. Plates containing unamended PDA were maintained as untreated control. Each petri dish was inoculated with a 5 mm plug of pure culture of *M. phaseolina* cut from the periphery of its actively growing 5 days old culture. Each treatment was replicated thrice under completely randomized design (CRD) and incubated at 28 ± 2°C temperature. Radial growth of colony in chitosan amended plates was measured when the mycelial growth in control plate was full. The mycelial inhibition was calculated using the formula mentioned above.

**Statistical analysis**

The experiment was conducted in completely randomized design (CRD) and the data was statistically analyzed as per the standard procedures suggested by Gomez and Gomez (1984). The critical differences were calculated at P = 0.05. The original data was transformed to arcsine values wherever necessary, in order to bring the data under normal distribution before analysis and the actual percentage values along with their corresponding transformed values are given in tables.

**RESULTS AND DISCUSSION**

**Soil amendments**

The aqueous extracts of five organic soil amendments *viz.,* neem cake, castor cake, groundnut cake, farm yard manure and vermi compost were evaluated for their inhibitory effect on *M. phaseolina* at 5%, 10% and 20% and the results indicate that, all the organic soil amendments had significant inhibitory effect on *M. phaseolina* at 10% and 20% concentrations. Neem cake, castor cake and groundnut cake showed mycelial inhibition even at 5% but farm yard manure and vermi compost did not show any inhibition at 5% concentration. It was also evident from the results that, there was a gradual decrease in growth of the pathogen with the increase in concentration of aqueous extracts of organic amendments.

Among the soil amendments tested, significantly highest mean mycelial inhibition was observed with neem cake (53.27%) followed by castor cake (47.22%) and least was observed with farm yard manure (13.88%). Across the organic soil amendments and their concentrations tested, significantly highest mycelial inhibition was recorded with neem cake (62.96%) at 20%, which was at par with its 10% (58.34%) followed by castor cake at 20% (56.48%) and no inhibition was observed with farm yard manure and vermi compost at 5% concentration (Table 1).

**Table 1. Effect of aqueous extracts of organic amendments against *Macrophomina phaseolina* under *in vitro* conditions**

| Treatment / Concentration | Per cent inhibition of mycelial growth over control | | | |
|---|---|---|---|---|
| | 5% | 10% | 20% | Mean |
| Neem cake | 38.52 * (38.30) ** | 58.34 (49.79) | 62.96 (52.50) | 53.27 (46.87) |
| Castor cake | 31.67 (34.23) | 53.52 (47.00) | 56.48 (48.71) | 47.22 (43.31) |
| Groundnut cake | 12.031 (20.26) | 2.96 (21.00) | 53.70 (47.10) | 26.23 (29.46) |
| Farm yard manure | 0.00 (0.00) | 20.37 (26.77) | 21.29 (27.45) | 13.88 (18.07) |
| Vermi compost | 0.00 (0.00) | 5.56 (11.03) | 53.33 (46.89) | 19.62 (19.30) |
| Mean | 13.70 (15.46) | 25.12 (25.93) | 41.29 (37.11) | |

| Factors | SE(m)± | C.D. (p=0.05) |
|---|---|---|
| Treatment (A) | 1.011 | 2.912 |
| Concentration (B) | 0.715 | 2.059 |
| Interaction (AxB) | 1.752 | 5.044 |

* Mean of three replications
** Values in parenthesis are angular transformed values

All the organic soil amendments showed their highest mycelial inhibition @ 20 per cent concentration. Significantly highest mycelial inhibition at 20 per cent concentration was recorded by neem cake (62.96%), followed by castor cake (56.48%) which was on par with groundnut cake (53.70%) and vermi compost (53.33%) and least mycelial inhibition at 20 per cent was observed with farm yard manure (21.29%).

Dhingani *et al*. (2013) recorded maximum mycelial inhibition (59.40%) with the extracts of neem cake under *in vitro* conditions. Similarly, Meena *et al.* (2014) also reported the dominance of neem cake in inhibiting the mycelial growth of *M. phaseolina* (52.40%) at 20% concentration followed by 42.61% and 29.60% inhibition at 15% and 10% concentrations respectively. The substances present in neem seed cake *viz.,* lysine, triterpenoids, azadirachtin, salannin, nimbin and gedunin could be responsible for its fungitoxic effect against *Macrophomina phaseolina* (Rashmi, 2016).

**Fungicides**

The efficacy of eight fungicides *viz.,* carbendazim, mancozeb, tebuconazole, propiconazole, tebuconazole + trifloxystrobin, azoxystrobin + tebuconazole, azoxystrobin + difenoconazole and carboxin + thiram was tested in inhibing the mycelial growth of *M. phaseolina* at 50, 100, 250, 500 and 1000 ppm concentrations and the results are presented in table 2.

All the fungicides tested were effective in inhibiting the mycelial growth of *M. phaseolina* at all concentrations in the study. Of these, significantly highest mean mycelial inhibition was observed with carbendazim (100.00%) followed by mancozeb (96.70%) which was at par with tebuconazole + trifloxystrobin (94.19%) and the least (47.19%) was observed with propiconazole.

Complete inhibition of *M. phaseolina* at all the concentrations tested was observed only by carbendazim. Fungicides, mancozeb and

**Table 2. Effect of fungicides on the mycelial growth of *Macrophomina phaseolina* under *in vitro* conditions**

| Treatment / Concentration | Per cent inhibition of mycelial growth over control | | | | | |
|---|---|---|---|---|---|---|
| | 50 ppm | 100 ppm | 250 ppm | 500 ppm | 1000 ppm | Mean |
| Carbendazim | 100.00 * (89.70) ** | 100.00 (89.70) | 100.00 (89.70) | 100.00 (89.70) | 100.00 (89.70) | 100.00 (89.70) |
| Mancozeb | 92.00 (76.49) | 94.07 (78.34) | 97.41 (84.40) | 100.00 (89.70) | 100.00 (89.70) | 96.70 (83.72) |
| Tebuconazole + Trifloxystrobin | 84.26 (66.74) | 92.59 (76.92) | 94.07 (78.34) | 100.00 (89.70) | 100.00 (89.70) | 94.19 (80.28) |
| Tebuconazole | 48.70 (44.26) | 72.59 (58.76) | 97.04 (84.02) | 97.22 (84.21) | 100.00 (89.70) | 83.11 (72.19) |
| Azoxystrobin + Tebuconazole | 63.89 (53.07) | 70.93 (57.41) | 81.85 (65.02) | 83.15 (65.80) | 84.63 (67.03) | 76.89 (61.67) |
| Azoxystrobin + Difenoconazole | 52.22 (46.29) | 56.48 (48.75) | 63.89 (53.09) | 69.44 (56.46) | 73.15 (58.80) | 63.04 (52.68) |
| Carboxin + Thiram | 31.85 (34.21) | 41.67 (39.91) | 63.33 (52.84) | 71.30 (57.64) | 79.26 (62.97) | 57.48 (49.52) |
| Propiconazole | 32.41 (34.69) | 39.81 (39.08) | 47.22 (43.40) | 54.44 (47.56) | 62.04 (52.01) | 47.19 (43.35) |
| Mean | 56.15 (49.53) | 63.13 (54.35) | 71.65 (61.20) | 75.06 (64.53) | 77.67 (66.66) | |

| Factors | SE(m)± | C.D. (p=0.05) |
|---|---|---|
| Fungicide (A) | 1.22 | 3.523 |
| Concentration (B) | 0.91 | 2.626 |
| Interaction (AxB) | 2.74 | 7.877 |

* Mean of three replications
** Values in parenthesis are angular transformed values

tebuconazole + trifloxystrobin could inhibit the pathogen by 92.00% and 84.26% at 50 ppm; 94.07% and 92.59% at 100 ppm; 97.41% and 94.07% at 250 ppm respectively but complete inhibition of the pathogen was observed at 500 ppm and 1000 ppm. Whereas, in case of tebuconazole, complete inhibition of the pathogen was observed at 1000 ppm. Propiconazole was the least effective among all fungicides, in inhibiting the growth of the pathogen at all concentration tested.

Similar results were reported by Dubey and Kumar (2003), where the growth of *Macrophomina phaseolina* was completely inhibited by carbendazim; while, mancozeb inhibited the growth by 87.30% at 30 ppm concentration.

In a study conducted by Chaudhary *et al.* (2017), complete mycelial inhibition of *Macrophomina phaseolina* was obtained by carbendazim and mancozeb at 250 ppm and 1500 ppm.

Hussain *et al*. (2014) also reported the maximum mycelial growth inhibition by fungicides benomyl (73.6%) and carbendazim (66.4%) fungicides at 100 ppm under *in vitro* conditions.

**Table 3. Effect of chitosan against *Macrophomina phaseolina* under *in vitro* conditions**

| Chitosan (mg ml$^{-1}$) | Radial growth of pathogen (mm) | Per cent inhibition of mycelial growth over control |
|---|---|---|
| 0.5 | 90.00 * | 0.00 * (0.00) * * |
| 1.0 | 88.33 | 1.85 (4.54) |
| 1.5 | 71.67 | 20.37 (26.65) |
| 2.0 | 30.00 | 66.67 (54.76) |
| 2.5 | 0.00 | 100.00 (90.00) |
| 3.0 | 0.00 | 100.00 (90.00) |
| **SE(m)±** | 2.10 | |
| **CD (p=0.05)** | 6.45 | |

* Mean of three replications
** Values in parenthesis are angular transformed values

**Chitosan**

Chitosan when tested against *M. phaseolina,* complete mycelial inhibition (100.00%) was observed at the concentration of 2.5 mg ml$^{-1}$ followed by 66.67% inhibition at 2.0 mg ml$^{-1}$. Chitosan concentration of 0.5 mg ml$^{-1}$ and 1 mg ml$^{-1}$ did not show any kind of significant inhibition of the pathogen over control (Table 3).

It is well established that chitosan is non toxic and biodegradable, directly inhibits the fungal growth and induces defense responses when applied to plants. In the present study it was observed that chitosan could inhibit (20.37%) the mycelial growth of *Macrophomina phaseolina* even at a concentration of 1.5 mg ml$^{-1}$.

Similar results were reported by Abdeen *et al.* (2013), who observed that, chitosan could cause complete inhibition of mycelial growth of various pathogens *viz., M. phaseolina, F. oxysporum, Phytophthora* sp., *Ramularia* sp., *F. solani* and *Phoma* sp. at 4000 ppm (4 mg ml$^{-1}$).

Chatterjee *et al*. (2014) reported the minimum inhibitory concentration (MIC) of water soluble s-chitosan for *M. phaseolina* as 12.5 g l$^{-1}$ on PDA through poisoned food technique.

## CONCLUSION

Different organic soil amendments, fungicides and chitosan at various concentrations were evaluated for their efficacy in inhibiting mycelial growth of *Macrophomina phaseolina* under *in vitro* conditions by using poisoned food technique. Neem cake at 20%, carbendazim at 50 ppm and chitosan at 2.5 mg ml$^{-1}$ concentration were found effective in controlling the mycelial growth of *M. phaseolina* under *in vitro* conditions. Further, the study suggests the evaluation of these component strategies under field conditions will help in developing a viable and potential integrated disease management strategy against charcoal rot disease (*M. phaseolina*) of maize.

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# HETEROSIS AND COMBINING ABILITY STUDIES TO IDENTIFY THE SUPERIOR HYBRIDS AND PARENTS FOR GRAIN YIELD AND YIELD CONTRIBUTING TRAITS IN SORGHUM (*Sorghum bicolor* L. Moench)

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## ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station (RARS), Palem to study the heterosis and combining ability of 64 genotypes for grain yield and yield related traits in sorghum [*Sorghum bicolor* (L.) Moench]. Fourteen parents including six male sterile (A lines) and eight restorers (R lines) were crossed in line × tester mating design to generate 48 $F_1$ hybrids. Evaluation of hybrids along with the parents and standard checks (CSV-41 and CSH-16) was carried out using a Randomized Block Design during *Rabi* 2020-21. Data was collected on eight quantitative traits *viz.*, days to 50 per cent flowering, days to maturity, plant height (cm), 100 seed weight (g), grain yield per plot (kg), grain yield per plant (g), fodder yield per plot (kg) and fodder yield per plant (g). Experimental results revealed that among the hybrids ICSA 418 × ICSR 13025 recorded maximum grain yield plant$^{-1}$ with 81.77, 62.32, 60.12 and 50.46 percent heterosis over mid parent, better parent and standard checks (CSV-41 and CSH-16), respectively. Variance due to *sca* was higher than *gca* and the ratio of variance of general to specific combing ability was less than unity for all the traits studied indicating the preponderance of non-additive gene action governing in the inheritance of these traits.

**Keywords:** Combining ability, gene action, heterosis, male sterile line, sorghum

Sorghum [*Sorghum bicolor* (L.) Monech] crop has not only proved its potential in drought prone areas, but also has displayed its enormous response to high input management conditions. Improvement of sorghum is much emphasized in crop breeding because of its importance as food and fodder crop for several million people in Asia and Africa. Sorghum offers wide potential to exploit heterosis and recombination breeding owing to its amenable floral biology (Umesha, 2003). Grain yield and yield components have been recognized to be quantitatively inherited and have high genetic variability. The type of gene action however, varies considerably among populations providing breeders options of selecting the most appropriate parents for the desired breeding purposes in either population or hybrid development (Alfonso, 1999). Estimating heterosis and combing abilities for grain yield and yield attributing traits in the breeding population would assist in identifying the most valuable heterotic groups for hybrid development. Furthermore, analysis will dissect the nature of gene action for trait of interest operating in particular population.

## MATERIAL AND METHODS

Sorghum genotypes studied in the experiment consisted of 14 parents (obtained from ICRISAT) and their 48 hybrids. Twelve parents, comprising of six male sterile lines ICSA 418, ICSA 419, ICSA 427, ICSA 433, ICSA 435 and ICSA 29004 (A lines, tolerant to sorghum shoot fly) and restorers *viz.,* ICSR 13004, ICSR 13009, ICSR 13025, ICSR 13031, ICSR 13042, ICSR 13043, ICSR 13046 and ICSR 29 (R lines, tolerant to sorghum shoot fly and high yielding) were crossed in line × tester mating design, during late *Kharif*, 2019. Fourteen parents and their 48 hybrids were evaluated during *rabi* 2020-2021 under irrigated conditions. Each entry was grown in two rows of four-meter length each, adopting randomized block design with two replications. The inter-row and inter-plant spacings were 45 cm and 15 cm respectively. Recommended package of practices were followed to raise a healthy crop. The biometrical observations were recorded on five randomly selected plants from each

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**Table 1. Analysis of variance for combining ability of parents and hybrids in sorghum**

| Source of variation | Degrees | DFF of freedom | DM | PH | 100 S.wt | GY/plot (kg) | GY/plant (g) | FY/plot (g) | FY/plant (Kg) |
|---|---|---|---|---|---|---|---|---|---|
| **Replicates** | 1 | 3.010 | 0.844 | 6.000 | 0.010 | 0.157 ** | 13.840 | 0.022 | 162.266 ** |
| **Parents** | 13 | 10.189 *** | 11.354 *** | 7083.802 *** | 0.448 *** | 0.224 *** | 294.198 *** | 0.411 *** | 1382.034 ** |
| **Crosses** | 47 | 32.377 *** | 47.409 *** | 1338.169 *** | 0.324 *** | 0.417 *** | 402.848 *** | 0.962 *** | 3838.277 *** |
| **Parents vs crosses** | 1 | 154.667 *** | 307.991 *** | 8668.387 *** | 15.552 *** | 0.083 * | 559.262 *** | 4.030 *** | 272.084 *** |
| **Line Effect** | 5 | 69.885 | 59.235 | 481.342 | 0.288 | 0.611 | 586.200 | 1.305 | 3120.400 |
| **Tester Effect** | 7 | 18.308 | 26.808 | 6211.304 *** | 0.415 | 0.187 | 138.369 | 1.407 | 2744.222 |
| **Line × Tester Eff.** | 35 | 29.833 *** | 49.840 *** | 485.946 *** | 0.311 *** | 0.435 *** | 429.551 *** | 0.825 *** | 4159.642 *** |
| **Error** | 47 | 0.819 | 1.099 | 2.723 | 0.053 | 0.021 | 8.870 | 0.025 | 20.360 |
| **Total** | 95 | 16.455 | 24.008 | 663.452 | 0.186 | 0.218 | 203.838 | 0.489 | 1910.718 |
| $\hat{\sigma}^2_{gca}$ | | 3.095 | 2.995 | 238.858 | 0.022 | 0.027 | 25.309 | 0.095 | 208.039 |
| $\hat{\sigma}^2_{sca}$ | | 14.530 | 24.371 | 241.820 | 0.130 | 0.209 | 210.794 | 0.401 | 2069.934 |
| $\hat{\sigma}^2_{sca}/\hat{\sigma}^2_{gca}$ | | 4.694 | 8.137 | 1.012 | 5.909 | 7.740 | 8.328 | 4.221 | 9.949 |

DFF- days to 50 % flowering, DM- days to maturity, PH- plant height (cm), 100 S.wt- 100 seed weight (g), GY/plot (Kg)- grain yield per plot (kg), GY/plant (g)- grain yield per plant (g), FY/plot (Kg)- fodder yield per plot (kg) and Fy/plant (g)- fodder yield per plant (g) variant per replication. Quantitative traits observed were days to 50 per cent flowering, days to maturity, plant height (cm), 100 seed weight (g), grain yield per plot (kg), grain yield per plant (g), fodder yield per plot (kg) and fodder yield per plant (g). The replication-wise mean values of the genotypes were subjected to analysis of variance (Panse and Sukhatme, 1985), heterosis (Gowen, 1952) and combining ability analysis (Kempthorne, 1957).

## RESULTS AND DISCUSSION

Analysis of variance for all the grain yield and yield component traits studied were presented in Table 1. Variance due to both parents as well as hybrids was highly significant for all the traits studied. Variance due to lines was non-significant for traits under study. Except for plant height, variance due to testers was non-significant for all the other traits investigated. Variance due to parents vs crosses was highly significant for all traits observed. Variance due to interaction effects of lines and testers was also highly significant for all the characters (Table 1). SCA variance was found to be greater than GCA variance for all characters observed. Ratio of variance of general to specific combing ability was less than unity for all the traits studied indicating the preponderance of non-additive gene action governing these traits. Non-additive gene action for different traits similar to present study was reported by Mengistu *et al.*, 2020, Akata *et al.*, 2017, Sayed and said 2016, Jain and patel 2016, Tariq *et al.*, 2012 and Vinay kumar *et al.*, 2011. Since selection is difficult for non-additively controlled traits, heterosis breeding is an ideal option for improvement of these traits. On the other hand, recombination breeding with selection at later generation could be done for development of varieties with improved grain yield and yield attributing traits. Selection of parents based on combination of different standards would increase the probability of success in any breeding program (Umesha, 2003). According to Harer and Bapat, 1982, *per se* performance and nature of combining ability of the parents provide the criteria for the choice of parents for hybridization program.

Among lines, ICSA 419 recorded significant *gca* in desirable direction for all traits except 100 seed weight. In testers, ICSR 13042 showed significant desirable *gca* for traits days to 50 per cent flowering, days to maturity, grain yield plot$^{-1}$, grain yield plant$^{-1}$, fodder yield plot$^{-1}$ and fodder yield plant$^{-1}$ (Table 2). However, both ICSA 433 and ICSR 13031 were superior in terms of *per se* performance for grain yield plant$^{-1}$ and most of yield attributing traits studied. The potential of a hybrid might be assessed by comparing mean performance with heterotic manifestation. Especially, standard heterosis is a better criterion for hybrid evaluation (Sharma, 1994).

ICSA 419 x ICSR 29 exhibited maximum *sca* effects for grain yield/plot while ICSA 418 × ICSR 13025 recorded maximum *sca* effects for grain yield plant$^{-1}$. ICSA 419 appears to be an outstanding general combiner for the trait and can be useful for future heterosis breeding programmes (Table 3). Earliness has been considered advantageous to stabilize sorghum yield as it will combat mid season and terminal drought conditions. The crosses ICSA 418 × ICSR 29 and ICSA 427 × ICSR 13031, both or either of the parents exhibited high *gca* effects for earliness and hence they could be exploited for development of early maturing hybrids. Hybrids ICSA 418 × ICSR 13042 for plant height, ICSA 29004 × ICSR 13046 for fodder yield per plot and ICSA 433 × ICSR 13004 for fodder yield per plant recorded highest *sca* performance coupled with significant standard heterosis and *per se* performance.

Significant standard heterosis in desirable direction was exhibited by most of the hybrids for all the traits studied. The superior hybrids with desirable heterosis (over CSV-41 and CSH-16 respectively) for days to 50 % flowering were ICSA 427 × ICSR 13046 (-13.33 and -6.40) and ICSA 427 × ICSR 13031 (-12.59 and -5.60). For days to maturity, ICSA 427 × ICSR 13046 (-9.95 and -10.36) and ICSA 427 × ICSR 13031 (-8.60 and -9.01) recorded maximum heterosis (Table 4). For plant height, the best hybrids with superior standard heterosis were ICSA 427 × ICSR 29 (-36.89 and -42.82), ICSA 435 × ICSR 29 (-33.72 and -39.95) and ICSA 433 × ICSR 29 (Table 5). For grain yield plant$^{-1}$, hybrid ICSA 418 × ICSR 13025 recorded 81.77, 62.32, 60.12 and 50.46 per cent heterosis over mid parent, better parent and standard check (over CSV-41 and CSH-16) respectively (Table 6). The highest significant standard heterosis (over CSV-41 and CSH-16) for fodder yield per plot were ICSA 419 × ICSR 29 (41.09 and 16.22) and ICSA 427 × ICSR 29 (32.09 and 8.81) and for fodder yield per plant were ICSA 419 × ICSR 13042 (37.43 and 23.46) and ICSA 418 × ICSR 13009 (36.95 and 23.03) (Table 7).

**Table 2. Estimates of general combining ability (*gca*) effects of parents for yield and its related traits in sorghum**

| Parents | Days to 50% flowering | Days to maturity | Plant height (cm) | 100 Seed weight (g) | Grain yield per plot (kg) | Grain yield per plant (g) | Fodder yield per plot (kg) | Fodder yield per plant (g) |
|---|---|---|---|---|---|---|---|---|
| ICSA 418 | 2.760 *** | 2.510 *** | -3.208 *** | 0.160 ** | 0.094 ** | 5.346 *** | 0.106 ** | 10.521 *** |
| ICSA 419 | -1.365 *** | -1.490 *** | -0.771 * | 0.067 | 0.223 *** | 6.636 *** | 0.237 *** | 9.853 *** |
| ICSA 427 | -2.177 *** | -2.052 *** | -7.333 *** | -0.102 | -0.279 *** | -6.649 *** | 0.160 *** | -0.299 |
| ICSA 433 | -1.802 *** | -1.490 *** | 6.229 *** | -0.202 *** | -0.198 *** | -6.716 *** | -0.410 *** | -20.646 *** |
| ICSA 435 | 2.010 *** | 1.698 *** | 6.667 *** | -0.015 | 0.116 *** | -2.494 *** | 0.220 *** | 13.340 *** |
| ICSA 29004 | 0.573 * | 0.823 ** | -1.583 *** | 0.092 | 0.044 | 3.879 *** | -0.314 *** | -12.769 *** |
| ICSR 13004 | 1.635 *** | 2.448 *** | -6.063 *** | -0.254 *** | -0.211 *** | 3.490 *** | -0.463 *** | -15.725 *** |
| ICSR13009 | -0.115 | -0.552 | 21.771 *** | -0.171 * | 0.065 | -0.457 | -0.036 | -7.200 *** |
| ICSR 13025 | 1.052 *** | 0.531 | 12.604 *** | 0.171 * | -0.036 | -4.427 *** | 0.323 *** | 19.371 *** |
| ICSR 13031 | 0.552 * | -0.385 | -2.979 *** | 0.121 | 0.177 *** | 4.547 *** | -0.480 *** | -18.586 *** |
| ICSR 13042 | -2.365 *** | -2.385 *** | 18.771 *** | -0.129 | 0.044 | 3.438 *** | 0.116 ** | 15.074 *** |
| ICSR 13043 | -0.531 * | 0.531 | -15.646 *** | -0.021 | 0.061 | -2.472 ** | -0.036 | -5.686 *** |
| ICSR 13046 | -0.698 ** | -1.302 *** | 16.938 *** | 0.296 *** | -0.142 *** | -1.153 | 0.075 | 17.334 *** |
| ICSR 29 | 0.469 | 1.115 *** | -45.396 *** | -0.013 | 0.041 | -2.966 *** | 0.500 *** | -4.584 *** |
| **CD @ 5% GCA (Line)** | 0.442 | 0.527 | 0.764 | 0.112 | 0.066 | 1.419 | 0.075 | 2.236 |
| **CD @ 5% GCA (Tester)** | 0.511 | 0.608 | 0.882 | 0.129 | 0.076 | 1.639 | 0.086 | 2.582 |

*P = 0.05; **P = 0.01; ***P = 0.001

**Table 3. Estimates of specific combining ability (*sca*) effects of hybrids for yield and its related traits in sorghum**

| Hybrid | Days to 50% flowering | Days to maturity | Plant height (cm) | 100 Seed weight (g) | Grain yield per plot (kg) | Grain yield per plant (g) | Fodder yield per plant (kg) | Fodder yield per plant (g) |
|---|---|---|---|---|---|---|---|---|
| ICSA 418 × ICSR 13004 | -1.260 * | -2.510 ** | -18.375 *** | -0.077 | 0.068 | -7.701 *** | -0.686 *** | -54.848 *** |
| ICSA 418 × ICSR 13009 | 0.990 | 0.490 | -13.208 *** | -0.510 ** | -0.118 | -1.480 | 0.703 *** | 68.167 *** |
| ICSA 418 × ICSR 13025 | -2.177 ** | 0.906 | 24.958 *** | 0.948 *** | 0.438 *** | 33.051 *** | 0.469 *** | 36.451 *** |
| ICSA 418 × ICSR 13031 | 3.323 *** | 1.823 * | 19.542 *** | 0.098 | -0.315 ** | -5.253 * | 0.512 *** | -14.488 *** |
| ICSA 418 × ICSR 13042 | 3.740 *** | 4.323 *** | -23.208 *** | -0.102 | -0.557 *** | -22.759 *** | -0.189 | -23.758 *** |
| ICSA 418 × ICSR 13043 | 0.406 | 2.406 ** | 5.708 *** | -0.060 | 0.515 *** | 11.330 *** | -0.362 ** | -33.353 *** |
| ICSA 418 × ICSR 13046 | 1.573 * | 3.240 *** | -4.375 *** | 0.073 | -0.431 *** | -0.748 | -0.613 *** | 4.308 |
| ICSA 418 × ICSR 29 | -6.594 *** | -10.677 *** | 8.958 *** | -0.369 * | 0.400 *** | -6.441 ** | 0.167 | 17.521 ** |
| ICSA 419 × ICSR 13004 | -6.135 *** | -10.010 *** | 11.688 *** | 0.117 | 0.269 ** | 22.684 *** | -0.721 *** | -65.530 *** |
| ICSA 419 × ICSR 13009 | 2.115 ** | 1.490 | -6.646 *** | -0.117 | -0.612 *** | -23.750 *** | 0.632 *** | 31.925 *** |
| ICSA 419 × ICSR 13025 | 2.948 *** | 3.406 *** | -16.479 *** | 0.242 | -0.491 *** | -11.624 *** | -0.667 *** | -57.466 *** |
| ICSA 419 × ICSR 13031 | -2.552 *** | -2.677 *** | 13.604 *** | -0.008 | 0.140 | -5.548 ** | -0.559 *** | -19.379 *** |
| ICSA 419 × ICSR 13042 | 5.365 *** | 9.323 *** | -6.146 *** | -0.358 * | -0.236 * | -0.654 | 0.345 ** | 47.371 *** |
| ICSA 419 × ICSR 13043 | -2.469 *** | -2.594 ** | -6.229 *** | -0.667 *** | -0.024 - | 2.010 | 0.192 | -26.564 *** |
| ICSA 419 × ICSR 13046 | -2.802 *** | -2.260 ** | 8.688 *** | 0.117 | 0.149 | -2.853 | 0.121 | 31.486 *** |
| ICSA 419 × ICSR 29 | 3.531 *** | 3.323 *** | 1.521 | 0.675 *** | 0.806 *** | 23.754 *** | 0.656 *** | 8.159 *** |
| ICSA 427 × ICSR 13004 | 6.177 *** | 5.052 *** | 13.750 *** | -0.115 | 0.211 * | 0.594 | 0.021 | 19.327 *** |
| ICSA 427 × ICSR 13009 | -4.073 *** | -1.948 * | 22.917 *** | -0.298 | -0.280 ** | -11.765 *** | 0.095 | -15.063 *** |
| ICSA 427 × ICSR 13025 | 4.760 *** | 5.969 *** | -27.917 *** | -0.390 * | -0.724 *** | -7.794 *** | -0.125 | 0.561 |
| ICSA 427 × ICSR 13031 | -6.240 *** | -6.615 *** | -5.333 *** | 0.760 *** | 0.053 | 14.717 *** | 0.594 *** | 38.252 *** |
| ICSA 427 × ICSR 13042 | -1.823 ** | -1.115 | -5.583 *** | 0.210 | -0.114 | -1.809 | -0.467 *** | -46.323 *** |
| ICSA 427 × ICSR 13043 | 3.344 *** | -0.531 | 0.333 | 0.052 | 0.494 *** | 10.650 *** | -0.495 *** | -28.268 *** |
| ICSA 427 × ICSR 13046 | -5.490 *** | -7.198 *** | 4.750 *** | -0.065 | 0.762 *** | 14.842 *** | -0.091 | -21.482 *** |
| ICSA 427 × ICSR 29 | 3.344 *** | 6.385 *** | -2.917 ** | -0.156 | -0.401 *** | -19.436 *** | 0.469 *** | 52.996 *** |
| ICSA 433 × ICSR 13004 | -4.198 *** | 2.490 ** | 9.688 *** | -0.015 | -0.286 ** | -21.745 *** | 1.311 *** | 97.748 *** |

**Table 3 (cont.)**

| Hybrid | Days to 50% flowering | Days to maturity | Plant height (cm) | 100 Seed weight (g) | Grain yield per plot (kg) | Grain yield per plant (g) | Fodder yield per plant (kg) | Fodder yield per plant (g) |
|---|---|---|---|---|---|---|---|---|
| ICSA 433 × ICSR 13009 | -1.448 * | -3.510 *** | -2.646 * | 0.352 * | 0.323 ** | 15.302 *** | -0.671 *** | -66.092 *** |
| ICSA 433 × ICSR 13025 | -4.115 *** | -6.594 *** | 20.521 *** | -0.440 ** | 0.274 ** | -2.438 | 0.105 | -16.502 *** |
| ICSA 433 × ICSR 13031 | 3.885 *** | 4.323 *** | -11.396 *** | -0.390 * | 0.556 *** | 11.373 *** | -0.732 *** | 1.374 |
| ICSA 433 × ICSR 13042 | -1.698 ** | -4.177 *** | 4.854 *** | 0.110 | 0.469 *** | 14.402 *** | 0.517 *** | 62.834 *** |
| ICSA 433 × ICSR 13043 | 0.969 | -0.594 | -9.729 *** | 0.352 * | -0.233 * | 1.622 | -0.466 *** | 1.494 |
| ICSA 433 × ICSR 13046 | 6.635 *** | 8.240 *** | -3.813 *** | -0.215 | -0.490 *** | -9.197 *** | 0.193 | -3.755 |
| ICSA 433 × ICSR 29 | -0.031 | -0.177 | -7.479 *** | 0.244 | -0.613 *** | -9.319 *** | -0.257 * | -77.102 *** |
| ICSA 435 × ICSR 13004 | 3.990 *** | 2.802 *** | -20.250 *** | -0.002 | -0.175 | 1.039 | 0.781 *** | 26.257 *** |
| ICSA 435 × ICSR 13009 | -0.260 | 1.302 | 8.917 *** | -0.285 | 0.390 *** | 3.580 | -1.031 *** | -32.013 *** |
| ICSA 435 × ICSR 13025 | -1.427 * | -1.281 | 23.583 *** | -0.127 | 0.560 *** | -8.519 *** | 0.290 ** | 32.911 *** |
| ICSA 435 × ICSR 13031 | 1.073 | 0.135 | -3.333 ** | -0.077 | -0.073 | 2.087 | -0.122 | -21.302 *** |
| ICSA 435 × ICSR 13042 | -1.010 | -1.365 | 10.917 *** | 0.073 | 0.470 *** | 16.546 *** | 0.642 *** | -0.957 |
| ICSA 435 × ICSR 13043 | -0.844 | 2.219 ** | 7.333 *** | 0.365 * | -0.857 *** | -11.675 *** | 0.639 *** | 15.133 *** |
| ICSA 435 × ICSR 13046 | 0.323 | -1.448 | -15.750 *** | 0.048 | 0.021 | -1.433 | -0.442 *** | 8.884 ** |
| ICSA 435 × ICSR 29 | -1.844 ** | -2.365 ** | -11.417 *** | 0.006 | -0.337 *** | -1.626 | -0.757 *** | -28.914 *** |
| ICSA 29004 × ICSR 13004 | 1.427 * | 2.177 ** | 3.500 ** | 0.092 | -0.087 | 5.131 * | -0.706 *** | -22.953 *** |
| ICSA 29004 × ICSR 13009 | 2.677 *** | 2.177 ** | -9.333 *** | 0.858 *** | 0.297 ** | 18.112 *** | 0.273 * | 13.077 *** |
| ICSA 29004 × ICSR 13025 | 0.010 | -2.406 ** | -24.667 *** | -0.233 | -0.057 | -2.677 | -0.071 | 4.046 |
| ICSA 29004 × ICSR 13031 | 0.510 | 3.010 *** | -13.083 *** | -0.383 * | -0.360 *** | -17.376 *** | 0.307 ** | 15.542 *** |
| ICSA 29004 × ICSR 13042 | -4.573 *** | -6.990 *** | 19.167 *** | 0.067 | -0.032 | -5.727 ** | -0.849 *** | -39.168 *** |
| ICSA 29004 × ICSR 13043 | -1.406 * | -0.906 | 2.583 * | -0.042 | 0.105 | -9.918 *** | 0.493 *** | 71.557 *** |
| ICSA 29004 × ICSR 13046 | -0.240 | -0.573 | 10.500 *** | 0.042 | -0.011 | -0.611 | 0.832 *** | -19.442 *** |
| ICSA 29004 × ICSR 29 | 1.594 * | 3.510 *** | 11.333 *** | -0.400 * | 0.145 | 13.066 *** | -0.278 * | -22.659 *** |
| **CD @ 5 % SCA** | 1.251 | 1.490 | 2.160 | 0.317 | 0.187 | 4.014 | 0.212 | 6.325 |

*P = 0.05; **P = 0.01; ***P = 0.001

**Table 4. Estimation of heterosis over mid parent, better parent and standard checks (CSV- 41 and CSH-16) for days to 50 % flowering and days to maturity in sorghum**

| S.No | Genotype | Days to 50% flowering | | | | Days to maturity | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heterosis over ⟶ | MPH | BPH | CSV-41 | CSH-16 | MPH | BPH | CSV-41 | CSH-16 |
| 1 | ICSA 418 × ICSR 13004 | -0.71 | -2.10 | 3.70 ** | 12.00 ** | -1.96 * | -2.17 * | 1.81 | 1.35 |
| 2 | ICSA 418 × ICSR 13009 | 1.44 | 1.44 | 4.44 ** | 12.80 ** | -1.32 | -1.75 | 1.81 | 1.35 |
| 3 | ICSA 418 × ICSR 13025 | -2.84 * | -4.20 ** | 1.48 | 9.60 ** | -1.08 | -1.72 | 3.17 ** | 2.70 ** |
| 4 | ICSA 418 × ICSR 13031 | 2.80 * | 0.00 | 8.89 ** | 17.60 ** | -1.51 | -2.56 ** | 3.17 ** | 2.70 ** |
| 5 | ICSA 418 × ICSR 13042 | 2.16 | 2.16 | 5.19 ** | 13.60 ** | 0.00 | 0.00 | 3.62 ** | 3.15 ** |
| 6 | ICSA 418 × ICSR 13043 | -1.42 | -2.80 * | 2.96 * | 11.20 ** | 1.54 | 0.87 | 4.52 ** | 4.05 ** |
| 7 | ICSA 418 × ICSR 13046 | 2.17 | 1.44 | 4.44 ** | 12.80 ** | 1.78 * | 0.00 | 3.62 ** | 3.15 ** |
| 8 | ICSA 418 × ICSR 29 | -9.29 ** | -9.93 ** | -5.93 ** | 1.60 | -10.24 ** | -10.43 ** | -6.79 ** | -7.21 ** |
| 9 | ICSA 419 × ICSR 13004 | -10.29 ** | -14.69 ** | -9.63 ** | -2.40 | -9.21 ** | -12.17 ** | -8.60 ** | -9.01 ** |
| 10 | ICSA 419 × ICSR 13009 | 0.75 | -2.88 * | 0.00 | 8.00 ** | -0.90 | -3.52 ** | -0.90 | -1.35 |
| 11 | ICSA 419 × ICSR 13025 | 2.21 | -2.80 * | 2.96 * | 11.20 ** | 0.67 | -3.02 ** | 1.81 | 1.35 |
| 12 | ICSA 419 × ICSR 13031 | -7.97 ** | -13.61 ** | -5.93 ** | 1.60 | -6.01 ** | -9.83 ** | -4.52 ** | -4.95 ** |
| 13 | ICSA 419 × ICSR 13042 | 2.24 | -1.44 | 1.48 | 9.60 ** | 4.05 ** | 0.87 | 4.52 ** | 4.05 ** |
| 14 | ICSA 419 × ICSR 13043 | -8.09 ** | -12.59 ** | -7.41 ** | 0.00 | -3.40 ** | -5.75 ** | -3.62 ** | -4.05 ** |
| 15 | ICSA 419 × ICSR 13046 | -6.77 ** | -9.49 ** | -8.15 ** | -0.80 | -3.67 ** | -4.98 ** | -4.98 ** | -5.41 ** |
| 16 | ICSA 419 × ICSR 29 | 2.96 * | -1.42 | 2.96 * | 11.20 ** | 1.57 | -1.74 | 2.26 * | 1.80 |
| 17 | ICSA 427 × ICSR 13004 | 2.84 * | 1.40 | 7.41 ** | 16.00 ** | 0.22 | 0.00 | 4.52 ** | 4.05 ** |
| 18 | ICSA 427 × ICSR 13009 | -12.95 ** | -12.95 ** | -10.37 ** | -3.20 * | -7.86 ** | -8.66 ** | -4.52 ** | -4.95 ** |
| 19 | ICSA 427 × ICSR 13025 | 0.00 | -1.40 | 4.44 ** | 12.80 ** | -1.08 | -1.29 | 3.62 ** | 3.15 ** |
| 20 | ICSA 427 × ICSR 13031 | -17.48 ** | -19.73 ** | -12.59 ** | -5.60 ** | -13.12 ** | -13.68 ** | -8.60 ** | -9.01 ** |
| 21 | ICSA 427 × ICSR 13042 | -12.95 ** | -12.95 ** | -10.37 ** | -3.20 * | -9.13 ** | -9.52 ** | -5.43 ** | -5.86 ** |
| 22 | ICSA 427 × ICSR 13043 | -4.26 ** | -5.59 ** | 0.00 | 8.00 ** | -5.47 ** | -6.49 ** | -2.26 * | -2.70 ** |
| 23 | ICSA 427 × ICSR 13046 | -15.22 ** | -15.83 ** | -13.33 ** | -6.40 ** | -11.95 ** | -13.85 ** | -9.95 ** | -10.36 ** |
| 24 | ICSA 427 × ICSR 29 | -2.14 | -2.84 * | 1.48 | 9.60 ** | 0.22 | 0.00 | 4.52 ** | 4.05 ** |
| 25 | ICSA 433 × ICSR 13004 | -9.42 ** | -12.59 ** | -7.41 ** | 0.00 | -0.66 | -1.30 | 2.71 ** | 2.25 * |
| 26 | ICSA 433 × ICSR 13009 | -6.62 ** | -8.63 ** | -5.93 ** | 1.60 | -7.93 ** | -7.93 ** | -5.43 ** | -5.86 ** |

**Table 4 (cont.)**

| S.No | Genotype | Days to 50% flowering | | | | Days to maturity | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Heterosis over ⟶** | **MPH** | **BPH** | **CSV-41** | **CSH-16** | **MPH** | **BPH** | **CSV-41** | **CSH-16** |
| 27 | ICSA 433 × ICSR 13025 | -10.14 ** | -13.29 ** | -8.15 ** | -0.80 | -10.68 ** | -11.64 ** | -7.24 ** | -7.66 ** |
| 28 | ICSA 433 × ICSR 13031 | -0.71 | -5.44 ** | 2.96 * | 11.20 ** | -2.39 ** | -3.85 ** | 1.81 | 1.35 |
| 29 | ICSA 433 × ICSR 13042 | -10.29 ** | -12.23 ** | -9.63 ** | -2.40 | -10.53 ** | -10.92 ** | -7.69 ** | -8.11 ** |
| 30 | ICSA 433 × ICSR 13043 | -5.07 ** | -8.39 ** | -2.96 * | 4.80 ** | -4.19 ** | -4.41 ** | -1.81 | -2.25 * |
| 31 | ICSA 433 × ICSR 13046 | 5.19 ** | 3.65 ** | 5.19 ** | 13.60 ** | 3.13 ** | 1.76 | 4.52 ** | 4.05 ** |
| 32 | ICSA 433 × ICSR 29 | -4.38 ** | -7.09 ** | -2.96 * | 4.80 ** | -4.16 ** | 4.78 ** | -0.90 - | 1.35 |
| 33 | ICSA 435 × ICSR 13004 | 6.81 ** | 4.20 ** | 10.37 ** | 19.20 ** | 2.41 ** | 1.74 | 5.88 ** | 5.41 ** |
| 34 | ICSA 435 × ICSR 13009 | -0.36 | -1.44 | 1.48 | 9.60 ** | -0.88 | -0.88 | 1.81 | 1.35 |
| 35 | ICSA 435 × ICSR 13025 | -1.79 | -4.20 ** | 1.48 | 9.60 ** | -3.27 ** | -4.31 ** | 0.45 | 0.00 |
| 36 | ICSA 435 × ICSR 13031 | -0.35 | -4.08 ** | 4.44 ** | 12.80 ** | -3.25 ** | -4.70 ** | 0.90 | 0.45 |
| 37 | ICSA 435 × ICSR 13042 | -4.73 ** | -5.76 ** | -2.96 * | 4.80 ** | -5.26 ** | -5.68 ** | -2.26 * | -2.70 ** |
| 38 | ICSA 435 × ICSR 13043 | -3.23 ** | -5.59 ** | 0.00 | 8.00 ** | 1.10 | 0.88 | 3.62 ** | 3.15 ** |
| 39 | ICSA 435 × ICSR 13046 | 0.37 | 0.00 | 1.48 | 9.60 ** | -2.68 ** | -3.96 ** | -1.36 | -1.80 |
| 40 | ICSA 435 × ICSR 29 | -2.53 * | -4.26 ** | 0.00 | 8.00 ** | -3.28 ** | -3.91 ** | 0.00 | -0.45 |
| 41 | ICSA 29004 × ICSR 13004 | 0.00 | -1.40 | 4.44 ** | 12.80 ** | 0.65 | 0.43 | 4.52 ** | 4.05 ** |
| 42 | ICSA 29004 × ICSR 13009 | 0.72 | 0.72 | 3.70 ** | 12.00 ** | -1.32 | -1.75 | 1.81 | 1.35 |
| 43 | ICSA 29004 × ICSR 13025 | -2.84 * | -4.20 ** | 1.48 | 9.60 ** | -5.42 ** | -6.03 ** | -1.36 | -1.80 |
| 44 | ICSA 29004 × ICSR 13031 | -4.20 ** | -6.80 ** | 1.48 | 9.60 ** | -1.94 * | -2.99 ** | 2.71 ** | 2.25 * |
| 45 | ICSA 29004 × ICSR 13042 | -12.95 ** | -12.95 ** | -10.37 ** | -3.20 * | -11.35 ** | -11.35 ** | -8.14 ** | -8.56 ** |
| 46 | ICSA 29004 × ICSR 13043 | -7.09 ** | -8.39 ** | -2.96 * | 4.80 ** | -2.86 ** | -3.49 ** | 0.00 | -0.45 |
| 47 | ICSA 29004 × ICSR 13046 | -3.62 ** | -4.32 ** | -1.48 | 6.40 ** | -3.11 ** | -4.80 ** | -1.36 | -1.80 |
| 48 | ICSA 29004 × ICSR 29 | -0.71 | -1.42 | 2.96 * | 11.20 ** | 0.65 | 0.43 | 4.52 ** | 4.05 ** |
| | **S.E** | 0.761 | 0.879 | 0.879 | 0.879 | 0.907 | 1.047 | 1.047 | 1.047 |
| | **C.D @ 5 %** | 1.532 | 1.769 | 1.769 | 1.769 | 1.825 | 2.107 | 2.107 | 2.107 |
| | **C.D @ 1%** | 2.044 | 2.361 | 2.361 | 2.361 | 2.436 | 2.812 | 2.812 | 2.812 |

*P = 0.05; **P = 0.01

Table 5. Estimation of heterosis over mid parent, better parent and standard checks (CSV- 41 and CSH-16) for plant height (cm) and 100 seed weight (g) in sorghum

| S.No | Genotype | Plant height (cm) | | | | 100 Seed weight (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heterosis over ⟶ | MPH | BPH | CSV-41 | CSH-16 | MPH | BPH | CSV-41 | CSH-16 |
| 1 | ICSA 418 × ICSR 13004 | -22.32 ** | -41.61 ** | -20.75 ** | -28.20 ** | -30.08 ** | -41.89 ** | -33.85 ** | -31.75 ** |
| 2 | ICSA 418 × ICSR 13009 | -9.19 ** | -33.66 ** | -1.73 | -10.97 ** | -41.46 ** | -51.35 ** | -44.62 ** | -42.86 ** |
| 3 | ICSA 418 × ICSR 13025 | 3.37 ** | -25.42 ** | 14.99 ** | 4.18 ** | 25.22 ** | 9.09 | 10.77 | 14.29 * |
| 4 | ICSA 418 × ICSR 13031 | -1.92 * | -27.29 ** | 2.88 ** | -6.79 ** | 9.09 | 8.00 | -16.92 * | -14.29 * |
| 5 | ICSA 418 × ICSR 13042 | -6.94 ** | -28.41 ** | -9.22 ** | -17.75 ** | -16.67 * | -23.73 ** | -30.77 ** | -28.57 ** |
| 6 | ICSA 418 × ICSR 13043 | -7.18 ** | -27.27 ** | -12.39 ** | -20.63 ** | -11.93 | -20.00 ** | -26.15 ** | -23.81 ** |
| 7 | ICSA 418 × ICSR 13046 | -4.77 ** | -29.64 ** | 0.58 | -8.88 ** | -7.32 | -22.97 ** | -12.31 | -9.52 |
| 8 | ICSA 418 × ICSR 29 | 1.62 | -2.33 | -27.67 ** | -34.46 ** | -32.26 ** | -44.00 ** | -35.38 ** | -33.33 ** |
| 9 | ICSA 419 × ICSR 13004 | -7.48 ** | -27.81 ** | -2.02 * | -11.23 ** | -31.82 ** | -39.19 ** | -30.77 ** | -28.57 ** |
| 10 | ICSA 419 × ICSR 13009 | -7.71 ** | -30.16 ** | 3.46 ** | -6.27 ** | -36.36 ** | -43.24 ** | -35.38 ** | -33.33 ** |
| 11 | ICSA 419 × ICSR 13025 | -19.65 ** | -40.00 ** | -7.49 ** | -16.19 ** | -9.68 | -15.15 * | -13.85 * | -11.11 |
| 12 | ICSA 419 × ICSR 13031 | -7.28 ** | -28.72 ** | 0.86 | -8.62 ** | -7.41 | -13.79 | -23.08 ** | -20.63 ** |
| 13 | ICSA 419 × ICSR 13042 | 0.57 - | 19.55 ** | 2.02 * | -7.57 ** | -35.04 ** | -35.59 ** | -41.54 ** | -39.68 ** |
| 14 | ICSA 419 × ICSR 13043 | -16.42 ** | -31.82 ** | -17.87 ** | -25.59 ** | -42.37 ** | -43.33 ** | -47.69 ** | -46.03 ** |
| 15 | ICSA 419 × ICSR 13046 | 0.00 | -23.39 ** | 9.51 ** | -0.78 | -15.15 * | -24.32 ** | -13.85 * | -11.11 |
| 16 | ICSA 419 × ICSR 29 | -7.49 ** | -8.71 ** | -30.55 ** | -37.08 ** | -8.27 | -18.67 ** | -6.15 | -3.17 |
| 17 | ICSA 427 × ICSR 13004 | -10.05 ** | -29.72 ** | -4.61 ** | -13.58 ** | -41.73 ** | -50.00 ** | -43.08 ** | -41.27 ** |
| 18 | ICSA 427 × ICSR 13009 | 3.98 ** | -21.21 ** | 16.71 ** | 5.74 ** | -44.88 ** | -52.70 ** | -46.15 ** | -44.44 ** |
| 19 | ICSA 427 × ICSR 13025 | -28.75 ** | -46.73 ** | -17.87 ** | -25.59 ** | -32.77 ** | -39.39 ** | -38.46 ** | -36.51 ** |
| 20 | ICSA 427 × ICSR 13031 | -20.90 ** | -39.10 ** | -13.83 ** | -21.93 ** | 20.39 ** | 16.98 * | -4.62 | -1.59 |
| 21 | ICSA 427 × ICSR 13042 | -2.98 ** | -22.27 ** | -1.44 | -10.70 ** | -17.86 * | -22.03 ** | -29.23 ** | -26.98 ** |
| 22 | ICSA 427 × ICSR 13043 | -16.54 ** | -31.82 ** | -17.87 ** | -25.59 ** | -20.35 ** | -25.00 ** | -30.77 ** | -28.57 ** |
| 23 | ICSA 427 × ICSR 13046 | -5.65 ** | -27.62 ** | 3.46 ** | -6.27 ** | -22.83 ** | -33.78 ** | -24.62 ** | -22.22 ** |
| 24 | ICSA 427 × ICSR 29 | -16.09 ** | -17.36 ** | -36.89 ** | -42.82 ** | -35.94 ** | -45.33 ** | -36.92 ** | -34.92 ** |
| 25 | ICSA 433 × ICSR 13004 | -9.09 ** | -25.69 ** | 0.86 | -8.62 ** | -45.59 ** | -50.00 ** | -43.08 ** | -41.27 ** |
| 26 | ICSA 433 × ICSR 13009 | -6.27 ** | -25.88 ** | 9.80 ** | -0.52 | -32.35 ** | -37.84 ** | -29.23 ** | -26.98 ** |

**Table 5 (cont.)**

| S.No | Genotype | Plant height (cm) | | | | 100 Seed weight (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Heterosis over** ⟶ | **MPH** | **BPH** | **CSV-41** | **CSH-16** | **MPH** | **BPH** | **CSV-41** | **CSH-16** |
| 27 | ICSA 433 × ICSR 13025 | -1.92 ** | -23.55 ** | 17.87 ** | 6.79 ** | -42.19 ** | -43.94 ** | -43.08 ** | -41.27 ** |
| 28 | ICSA 433 × ICSR 13031 | -20.51 ** | -36.05 ** | -9.51 ** | -18.02 ** | -33.93 ** | -40.32 ** | -43.08 ** | -41.27 ** |
| 29 | ICSA 433 × ICSR 13042 | 5.55 ** | -11.36 ** | 12.39 ** | 1.83 * | -30.58 ** | -32.26 ** | -35.38 ** | -33.33 ** |
| 30 | ICSA 433 × ICSR 13043 | -18.55 ** | -30.14 ** | -15.85 ** | -23.76 ** | -19.67 ** | -20.97 ** | -24.62 ** | -22.22 ** |
| 31 | ICSA 433 × ICSR 13046 | -7.17 ** | -25.60 ** | 6.34 ** | -3.66 ** | -35.29 ** | -40.54 ** | -32.31 ** | -30.16 ** |
| 32 | ICSA 433 × ICSR 29 | -14.75 ** | -20.74 ** | -31.70 ** | -38.12 ** | -31.39 ** | -37.33 ** | -27.69 ** | -25.40 ** |
| 33 | ICSA 435 × ICSR 13004 | -16.50 ** | -38.22 ** | -16.14 ** | -24.02 ** | -44.59 ** | -44.59 ** | -36.92 ** | -34.92 ** |
| 34 | ICSA 435 × ICSR 13009 | 9.46 ** | -21.21 ** | 16.71 ** | 5.74 ** | -50.00 ** | -50.00 ** | -43.08 ** | -41.27 ** |
| 35 | ICSA 435 × ICSR 13025 | 9.33 ** | -22.24 ** | 19.88 ** | 8.62 ** | -32.86 ** | -36.49 ** | -27.69 ** | -25.40 ** |
| 36 | ICSA 435 × ICSR 13031 | -7.67 ** | -32.59 ** | -4.61 ** | -13.58 ** | -24.19 ** | -36.49 ** | -27.69 ** | -25.40 ** |
| 37 | ICSA 435 × ICSR 13042 | 21.02 ** | -8.41 ** | 16.14 ** | 5.22 ** | -32.33 ** | -39.19 ** | -30.77 ** | -28.57 ** |
| 38 | ICSA 435 × ICSR 13043 | 1.55 | -21.77 ** | -5.76 ** | -14.62 ** | -20.90 ** | -28.38 ** | -18.46 ** | -15.87 * |
| 39 | ICSA 435 × ICSR 13046 | -4.16 ** | -30.24 ** | -0.29 | -9.66 ** | -28.38 ** | -28.38 ** | -18.46 ** | -15.87 * |
| 40 | ICSA 435 × ICSR 29 | -4.76 ** | -10.51 ** | -33.72 ** | -39.95 ** | -38.26 ** | -38.67 ** | -29.23 ** | -26.98 ** |
| 41 | ICSA 29004 × ICSR 13004 | -13.21 ** | -31.63 ** | -7.20 ** | -15.93 ** | -32.33 ** | -39.19 ** | -30.77 ** | -28.57 ** |
| 42 | ICSA 29004 × ICSR 13009 | -10.32 ** | -31.52 ** | 1.44 | -8.09 ** | -6.77 | -16.22 ** | -4.62 | -1.59 |
| 43 | ICSA 29004 × ICSR 13025 | -24.81 ** | -43.36 ** | -12.68 ** | -20.89 ** | -24.80 ** | -28.79 ** | -27.69 ** | -25.40 ** |
| 44 | ICSA 29004 × ICSR 13031 | -22.57 ** | -39.92 ** | -14.99 ** | -22.98 ** | -21.10 ** | -27.12 ** | -33.85 ** | -31.75 ** |
| 45 | ICSA 29004 × ICSR 13042 | 13.36 ** | -8.41 ** | 16.14 ** | 5.22 ** | -20.34 ** | -20.34 ** | -27.69 ** | -25.40 ** |
| 46 | ICSA 29004 × ICSR 13043 | -12.63 ** | -27.99 ** | -13.26 ** | -21.41 ** | -21.01 ** | -21.67 ** | -27.69 ** | -25.40 ** |
| 47 | ICSA 29004 × ICSR 13046 | -0.39 | -22.98 ** | 10.09 ** | -0.26 | -17.29 ** | -25.68 ** | -15.38 * | -12.70 |
| 48 | ICSA 29004 × ICSR 29 | -1.89 | -4.43 ** | -25.36 ** | -32.38 ** | -40.30 ** | -46.67 ** | -38.46 ** | -36.51 ** |
| | **S.E** | 1.315 | 1.519 | 1.519 | 1.519 | 0.193 | 0.222 | 0.222 | 0.222 |
| | **C.D @ 5 %** | 2.646 | 3.055 | 3.055 | 3.055 | 0.388 | 0.448 | 0.448 | 0.448 |
| | **C.D @ 1%** | 3.531 | 4.077 | 4.077 | 4.077 | 0.518 | 0.598 | 0.598 | 0.598 |

*P = 0.05; **P = 0.01

**Table 6. Estimation of heterosis over mid parent, better parent and standard checks (CSV- 41 and CSH-16) for grain yield per plot (kg) and grain yield per plant (g) in sorghum**

| S.No | Genotype | Grain yield per plot (kg) | | | | Grain yield per plant (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heterosis over ⟶ | MPH | BPH | CSV-41 | CSH-16 | MPH | BPH | CSV-41 | CSH-16 |
| 1 | ICSA 418 × ICSR 13004 | 7.65 | -17.85 ** | -3.75 | -8.88 | 19.03 ** | 0.17 | 13.70 ** | 6.85 |
| 2 | ICSA 418 × ICSR 13009 | 10.72 | -16.41 ** | 1.07 | -4.31 | 29.65 ** | 13.71 ** | 16.92 ** | 9.87 * |
| 3 | ICSA 418 × ICSR 13025 | 69.87 ** | 45.79 ** | 25.47 ** | 18.78 ** | 81.77 ** | 62.32 ** | 60.12 ** | 50.46 ** |
| 4 | ICSA 418 × ICSR 13031 | 20.60 ** | -1.91 | -3.49 | -8.63 | 15.67 ** | -7.03 * | 18.66 ** | 11.50 ** |
| 5 | ICSA 418 × ICSR 13042 | 7.75 | -4.68 | -23.59 ** | -27.66 ** | 2.36 | -10.25 * | -7.65 | -13.22 ** |
| 6 | ICSA 418 × ICSR 13043 | 55.49 ** | 20.62 ** | 34.85 ** | 27.66 ** | 46.57 ** | 28.54 ** | 32.18 ** | 24.21 ** |
| 7 | ICSA 418 × ICSR 13046 | -0.55 | -14.42 | -26.81 ** | -30.71 ** | 44.99 ** | 39.56 ** | 16.97 ** | 9.92 * |
| 8 | ICSA 418 × ICSR 29 | 36.19 ** | 1.49 | 27.61 ** | 20.81 ** | 17.40 ** | 2.60 | 6.36 | -0.05 |
| 9 | ICSA 419 × ICSR 13004 | 4.55 | -2.75 | 13.94 | 7.87 | 32.23 ** | 25.59 ** | 58.48 ** | 48.92 ** |
| 10 | ICSA 419 × ICSR 13009 | -26.48 ** | -32.59 ** | -18.50 * | -22.84 ** | -23.79 ** | -30.84 ** | -12.74 ** | -18.00 ** |
| 11 | ICSA 419 × ICSR 13025 | -11.62 | -18.09 * | -17.43 * | -21.83 ** | -12.12 ** | -21.71 ** | -1.21 | -7.17 |
| 12 | ICSA 419 × ICSR 13031 | 28.40 ** | 26.86 ** | 27.88 ** | 21.07 ** | -5.39 | -5.93 | 20.07 ** | 12.82 ** |
| 13 | ICSA 419 × ICSR 13042 | 11.11 | -0.27 | 0.54 | -4.82 | 9.49 ** | -0.61 | 25.42 ** | 17.85 ** |
| 14 | ICSA 419 × ICSR 13043 | 6.18 | 0.96 | 12.87 | 6.85 | 0.56 | -8.75 ** | 15.15 ** | 8.20 * |
| 15 | ICSA 419 × ICSR 13046 | 19.42 ** | 10.37 | 11.26 | 5.33 | 10.30 ** | -8.22 * | 15.82 ** | 8.83 * |
| 16 | ICSA 419 × ICSR 29 | 37.99 ** | 24.31 ** | 56.30 ** | 47.97 ** | 31.27 ** | 19.56 ** | 50.87 ** | 41.77 ** |
| 17 | ICSA 427 × ICSR 13004 | -16.76 ** | -28.38 ** | -16.09 * | -20.56 ** | -4.08 | -4.44 | 8.47 * | 1.93 |
| 18 | ICSA 427 × ICSR 13009 | -29.50 ** | -40.13 ** | -27.61 ** | -31.47 ** | -20.71 ** | -24.17 ** | -14.57 ** | -19.73 ** |
| 19 | ICSA 427 × ICSR 13025 | -49.37 ** | -49.84 ** | -56.84 ** | -59.14 ** | -19.14 ** | -24.17 ** | -14.57 ** | -19.73 ** |
| 20 | ICSA 427 × ICSR 13031 | 5.28 | -2.18 | -3.75 | -8.88 | 8.14 ** | 1.80 | 29.93 ** | 22.10 ** |
| 21 | ICSA 427 × ICSR 13042 | -2.61 | -5.08 | -19.84 ** | -24.11 ** | -2.57 | -6.79 | 5.00 | -1.33 |
| 22 | ICSA 427 × ICSR 13043 | 15.85 * | 1.68 | 13.67 | 7.61 | 6.05 | 1.42 | 14.26 ** | 7.37 |
| 23 | ICSA 427 × ICSR 13046 | 37.85 ** | 36.99 ** | 17.16 * | 10.91 | 24.24 ** | 8.34 * | 22.05 ** | 14.69 ** |
| 24 | ICSA 427 × ICSR 29 | -38.52 ** | -48.61 ** | -35.39 ** | -38.83 ** | -34.32 ** | -36.94 ** | -28.96 ** | -33.25 ** |
| 25 | ICSA 433 × ICSR 13004 | -40.72 ** | -47.37 ** | -38.34 ** | -41.62 ** | -37.81 ** | -42.47 ** | -23.20 ** | -27.83 ** |

**Table 6 (cont.)**

| S.No | Genotype | Grain yield per plot (kg) | | | | Grain yield per plant (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Heterosis over ⟶** | **MPH** | **BPH** | **CSV-41** | **CSH-16** | **MPH** | **BPH** | **CSV-41** | **CSH-16** |
| 26 | ICSA 433 × ICSR 13009 | 3.04 | -9.76 | 9.12 | 3.30 | 4.60 | -7.42 * | 23.59 ** | 16.14 ** |
| 27 | ICSA 433 × ICSR 13025 | 14.24 * | 11.21 | 1.07 | -4.31 | -19.96 ** | -30.41 ** | -7.10 | -12.70 ** |
| 28 | ICSA 433 × ICSR 13031 | 34.84 ** | 29.70 ** | 27.61 ** | 20.81 ** | -4.18 | -6.28 * | 25.11 ** | 17.57 ** |
| 29 | ICSA 433 × ICSR 13042 | 35.42 ** | 27.43 ** | 15.82 * | 9.64 | 8.15 ** | -4.25 | 27.83 ** | 20.12 ** |
| 30 | ICSA 433 × ICSR 13043 | -21.96 ** | -29.26 ** | -20.91 ** | -25.13 ** | -14.18 ** | -24.04 ** | 1.41 | -4.71 |
| 31 | ICSA 433 × ICSR 13046 | -38.30 ** | -40.12 ** | -45.58 ** | -48.48 ** | -19.03 ** | -34.10 ** | -12.02 ** | -17.33 ** |
| 32 | ICSA 433 × ICSR 29 | -46.78 ** | -54.16 ** | -42.36 ** | -45.43 ** | -28.11 ** | -36.14 ** | -14.76 ** | -19.90 ** |
| 33 | ICSA 435 × ICSR 13004 | -18.29 ** | -27.92 ** | -15.55 * | -20.05 ** | 17.36 ** | 1.29 | 14.98 ** | 8.04 * |
| 34 | ICSA 435 × ICSR 13009 | 23.06 ** | 7.10 | 29.49 ** | 22.59 ** | 21.99 ** | 9.88 * | 12.99 ** | 6.18 |
| 35 | ICSA 435 × ICSR 13025 | 51.76 ** | 48.80 ** | 33.24 ** | 26.14 ** | -0.28 | -8.48 * | -9.73 * | -15.17 ** |
| 36 | ICSA 435 × ICSR 13031 | 17.83 ** | 12.53 | 10.72 | 4.82 | 12.30 ** | -7.59 * | 17.95 ** | 10.84 ** |
| 37 | ICSA 435 × ICSR 13042 | 56.40 ** | 48.20 ** | 32.71 ** | 25.63 ** | 47.66 ** | 32.97 ** | 36.82 ** | 28.57 ** |
| 38 | ICSA 435 × ICSR 13043 | -37.95 ** | -44.12 ** | -37.53 ** | -40.86 ** | -4.37 | -13.86 ** | -11.42 ** | -16.76 ** |
| 39 | ICSA 435 × ICSR 13046 | 12.71 | 10.18 | -1.34 | -6.60 | 26.23 ** | 25.18 ** | 4.92 | -1.41 |
| 40 | ICSA 435 × ICSR 29 | -17.06 ** | -29.00 ** | -10.72 | -15.48 * | 9.72 * | -1.53 | 2.08 | -4.07 |
| 41 | ICSA 29004 × ICSR 13004 | -15.54 * | -27.23 ** | -14.75 * | -19.29 ** | 21.12 ** | 14.32 ** | 29.77 ** | 21.94 ** |
| 42 | ICSA 29004 × ICSR 13009 | 17.34 ** | -0.22 | 20.64 ** | 14.21 * | 40.02 ** | 38.62 ** | 42.54 ** | 33.94 ** |
| 43 | ICSA 29004 × ICSR 13025 | 12.72 | 11.84 | -3.75 | -8.88 | 7.86 * | 6.72 | 7.54 | 1.06 |
| 44 | ICSA 29004 × ICSR 13031 | -0.15 | -7.08 | -8.58 | -13.45 * | -12.92 ** | -22.08 ** | -0.55 | -6.55 |
| 45 | ICSA 29004 × ICSR 13042 | 23.58 ** | 20.25 * | 1.88 | -3.55 | 12.29 ** | 11.13 ** | 14.35 ** | 7.45 |
| 46 | ICSA 29004 × ICSR 13043 | 12.14 | -1.44 | 10.19 | 4.31 | -1.70 | -2.69 | 0.07 | -5.96 |
| 47 | ICSA 29004 × ICSR 13046 | 9.29 | 8.78 | -6.97 | -11.93 | 24.70 ** | 14.21 ** | 15.09 ** | 8.15 * |
| 48 | ICSA 29004 × ICSR 29 | 5.73 | -11.51 * | 11.26 | 5.33 | 29.00 ** | 27.20 ** | 31.86 ** | 23.91 ** |
| | **S.E** | 0.113 | 0.131 | 0.131 | 0.131 | 2.443 | 2.822 | 2.822 | 2.822 |
| | **C.D @ 5 %** | 0.228 | 0.264 | 0.264 | 0.264 | 4.916 | 4.916 | 5.677 | 5.677 |
| | **C.D @ 1%** | 0.305 | 0.352 | 0.352 | 0.352 | 6.560 | 6.560 | 7.575 | 7.575 |

*P = 0.05; **P = 0.01

**Table 7. Estimation of heterosis over mid parent, better parent and standard checks (CSV- 41 and CSH-16) fodder yield per plant (kg) and fodder yield per plant (g) in sorghum**

| S.No | Genotype | Fodder yield per plot (kg) | | | | Fodder yield per plot (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heterosis over ⟶ | MPH | BPH | CSV-41 | CSH-16 | MPH | BPH | CSV-41 | CSH-16 |
| 1 | ICSA 418 × ICSR 13004 | -34.41 ** | -38.02 ** | -41.60 ** | -51.89 ** | -26.00 ** | -28.59 ** | -40.81 ** | -46.83 ** |
| 2 | ICSA 418 × ICSR 13009 | 16.19 ** | -2.21 | 20.03 ** | -1.12 | 44.11 ** | 21.22 ** | 36.95 ** | 23.03 ** |
| 3 | ICSA 418 × ICSR 13025 | 15.91 ** | -4.81 | 24.28 ** | 2.38 | 46.36 ** | 26.45 ** | 33.91 ** | 20.30 ** |
| 4 | ICSA 418 × ICSR 13031 | 14.40 ** | 11.54 * | -1.53 | -18.88 ** | 4.17 | 2.83 | -18.64 ** | -26.91 ** |
| 5 | ICSA 418 × ICSR 13042 | 4.19 | -3.45 | -5.09 | -21.82 ** | 17.23 ** | 10.96 ** | -4.22 | -13.96 ** |
| 6 | ICSA 418 × ICSR 13043 | -6.62 | -12.41 * | -16.13 ** | -30.91 ** | -9.33 ** | -17.72 ** | -22.17 ** | -30.08 ** |
| 7 | ICSA 418 × ICSR 13046 | -21.15 ** | -32.27 ** | -20.88 ** | -34.83 ** | 25.35 ** | 8.98 ** | 13.70 ** | 2.15 |
| 8 | ICSA 418 × ICSR 29 | 18.33 ** | 0.86 | 20.03 ** | -1.12 | 13.84 ** | -4.47 | 8.56 ** | -2.48 |
| 9 | ICSA 419 × ICSR 13004 | -36.87 ** | -38.99 ** | -38.37 ** | -49.23 ** | -36.45 ** | -36.68 ** | -47.52 ** | -52.85 ** |
| 10 | ICSA 419 × ICSR 13009 | 9.10 * | -0.55 | 22.07 ** | 0.56 | 17.93 ** | 1.91 | 15.13 ** | 3.43 |
| 11 | ICSA 419 × ICSR 13025 | -22.14 ** | -30.95 ** | -9.85 | -25.73 ** | -17.11 ** | -26.35 ** | -22.01 ** | -29.93 ** |
| 12 | ICSA 419 × ICSR 13031 | -29.69 ** | -34.12 ** | -33.45 ** | -45.17 ** | -3.26 | -5.12 | -21.93 ** | -29.86 ** |
| 13 | ICSA 419 × ICSR 13042 | 17.89 ** | 16.30 ** | 17.49 ** | -3.22 | 63.02 ** | 59.22 ** | 37.43 ** | 23.46 ** |
| 14 | ICSA 419 × ICSR 13043 | 8.89 | 6.05 | 7.13 | -11.75 ** | -7.90 ** | -13.90 ** | -18.55 ** | -26.83 ** |
| 15 | ICSA 419 × ICSR 13046 | -0.39 | -7.12 | 8.49 | -10.63 * | 38.65 ** | 24.00 ** | 29.37 ** | 16.22 ** |
| 16 | ICSA 419 × ICSR 29 | 28.24 ** | 18.54 ** | 41.09 ** | 16.22 ** | 34.94 ** | 16.33 ** | 32.18 ** | 18.75 ** |
| 17 | ICSA 427 × ICSR 13004 | -20.83 ** | -28.94 ** | -15.79 ** | -30.63 ** | -4.27 | -18.81 ** | -3.36 | -13.18 ** |
| 18 | ICSA 427 × ICSR 13009 | -16.12 ** | -17.57 ** | 1.19 | -16.64 ** | -29.87 ** | -31.65 ** | -18.65 ** | -26.92 ** |
| 19 | ICSA 427 × ICSR 13025 | -14.93 ** | -18.86 ** | 5.94 | -12.73 ** | -5.48 ** | -10.70 ** | 6.30 * | -4.51 |
| 20 | ICSA 427 × ICSR 13031 | -0.33 | -13.04 ** | 3.06 | -15.10 ** | 7.13 ** | -10.83 ** | 6.14 * | -4.65 |
| 21 | ICSA 427 × ICSR 13042 | -19.50 ** | -26.36 ** | -12.73 * | -28.11 ** | -25.94 ** | -36.12 ** | -23.96 ** | -31.69 ** |
| 22 | ICSA 427 × ICSR 13043 | -24.25 ** | -31.52 ** | -18.85 ** | -33.15 ** | -30.31 ** | -37.46 ** | -25.56 ** | -33.12 ** |
| 23 | ICSA 427 × ICSR 13046 | -16.16 ** | -16.76 ** | -1.36 | -18.74 ** | -17.57 ** | -22.66 ** | -7.94 ** | -17.30 ** |
| 24 | ICSA 427 × ICSR 29 | 11.22 ** | 10.98 * | 32.09 ** | 8.81 * | 5.85 ** | 3.45 | 23.13 ** | 10.62 ** |
| 25 | ICSA 433 × ICSR 13004 | -2.74 | -15.90 ** | 8.66 | -10.49 * | 34.69 ** | 17.36 ** | 30.97 ** | 17.66 ** |
| 26 | ICSA 433 × ICSR 13009 | -55.66 ** | -56.77 ** | -44.14 ** | -53.99 ** | -65.12 ** | -65.34 ** | -60.84 ** | -64.82 ** |

Table 7 (cont.)

| S.No | Genotype | Fodder yield per plot (kg) | | | | Fodder yield per plot (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Heterosis over →** | **MPH** | **BPH** | **CSV-41** | **CSH-16** | **MPH** | **BPH** | **CSV-41** | **CSH-16** |
| 27 | ICSA 433 × ICSR 13025 | -27.32 ** | -27.70 ** | -5.60 | -22.24 ** | -22.59 ** | -24.57 ** | -15.82 ** | -24.38 ** |
| 28 | ICSA 433 × ICSR 13031 | -64.40 ** | -70.04 ** | -61.29 ** | -68.11 ** | -24.17 ** | -35.20 ** | -27.69 ** | -35.04 ** |
| 29 | ICSA 433 × ICSR 13042 | -10.90 ** | -21.55 ** | 1.36 | -16.50 ** | 29.90 ** | 15.18 ** | 28.54 ** | 15.47 ** |
| 30 | ICSA 433 × ICSR 13043 | -44.15 ** | -51.38 ** | -37.18 ** | -48.25 ** | -22.39 ** | -28.31 ** | -19.99 ** | -28.12 ** |
| 31 | ICSA 433 × ICSR 13046 | -27.67 ** | -31.14 ** | -11.04 * | -26.71 ** | -16.16 ** | -18.89 ** | -9.49 ** | -18.69 ** |
| 32 | ICSA 433 × ICSR 29 | -29.00 ** | -31.80 ** | -11.88 * | -27.41 ** | -69.63 ** | -69.91 ** | -65.80 ** | -69.28 ** |
| 33 | ICSA 435 × ICSR 13004 | 14.58 ** | 10.55 * | 12.05 * | -7.69 | 13.87 ** | 0.55 | 8.80 ** | -2.26 |
| 34 | ICSA 435 × ICSR 13009 | -41.97 ** | -47.03 ** | -34.97 ** | -46.43 ** | -28.21 ** | -29.72 ** | -20.60 ** | -28.67 ** |
| 35 | ICSA 435 × ICSR 13025 | 5.27 | -6.50 | 22.07 ** | 0.56 | 24.69 ** | 23.35 ** | 33.48 ** | 19.91 ** |
| 36 | ICSA 435 × ICSR 13031 | -14.77 ** | -20.27 ** | -19.19 ** | -33.43 ** | -15.66 ** | -27.00 ** | -21.00 ** | -29.03 ** |
| 37 | ICSA 435 × ICSR 13042 | 27.21 ** | 25.29 ** | 26.99 ** | 4.62 | 14.04 ** | 2.50 | 10.92 ** | -0.35 |
| 38 | ICSA 435 × ICSR 13043 | 23.51 ** | 20.10 ** | 21.73 ** | 0.28 | 6.66 ** | -0.05 | 8.16 ** | -2.83 |
| 39 | ICSA 435 × ICSR 13046 | -18.60 ** | -23.98 ** | -11.21 * | -26.85 ** | 11.11 ** | 9.11 ** | 18.07 ** | 6.07 * |
| 40 | ICSA 435 × ICSR 29 | -16.02 ** | -22.25 ** | -7.47 | -23.78 ** | -25.38 ** | -27.16 ** | -17.23 ** | -25.64 ** |
| 41 | ICSA 29004 × ICSR 13004 | -59.07 ** | -63.22 ** | -56.54 ** | -64.20 ** | -19.61 ** | -22.45 ** | -35.72 ** | -42.26 ** |
| 42 | ICSA 29004 × ICSR 13009 | -24.31 ** | -25.73 ** | -8.83 | -24.90 ** | -4.62 | -19.79 ** | -9.38 ** | -18.59 ** |
| 43 | ICSA 29004 × ICSR 13025 | -26.28 ** | -29.78 ** | -8.32 | -24.48 ** | 10.41 ** | -4.64 | 0.98 | -9.28 ** |
| 44 | ICSA 29004 × ICSR 13031 | -25.16 ** | -34.63 ** | -22.75 ** | -36.36 ** | 9.31 ** | 7.86 * | -14.66 ** | -23.33 ** |
| 45 | ICSA 29004 × ICSR 13042 | -46.20 ** | -50.72 ** | -41.77 ** | -52.03 ** | -10.74 ** | -15.54 ** | -27.10 ** | -34.51 ** |
| 46 | ICSA 29004 × ICSR 13043 | -7.78 | -16.52 ** | -1.36 | -18.74 ** | 46.93 ** | 33.29 ** | 26.08 ** | 13.27 ** |
| 47 | ICSA 29004 × ICSR 13046 | -3.03 | -3.59 | 13.92 ** | -6.15 | -5.28 * | -17.67 ** | -14.10 ** | -22.84 ** |
| 48 | ICSA 29004 × ICSR 29 | -23.55 ** | -23.82 ** | -9.34 | -25.31 ** | -25.48 ** | -37.48 ** | -28.96 ** | -36.18 ** |
| | **S.E** | 0.128 | 0.148 | 0.148 | 0.148 | 3.850 | 4.446 | 4.446 | 4.446 |
| | **C.D @ 5 %** | 0.259 | 0.299 | 0.299 | 0.299 | 7.747 | 8.945 | 8.945 | 8.945 |
| | **C.D @ 1%** | 0.345 | 0.399 | 0.399 | 0.399 | 10.338 | 11.937 | 11.937 | 11.937 |

*P = 0.05; **P = 0.01

From the study it can be revealed that non additive gene action was predominant for all the traits. Parents ICSA 419 and ICSR 13031, were good combiners with high *per se* performance for grain yield and many of the yield attributing traits, thus could be used for development of sorghum with superior grain yield. Considering grain yield plant$^{-1}$ alone, the hybrid ICSA 418 × ICSR 13025 might be the best choice. In all the hybrids investigated, significant standard heterosis shows strong positive association with highly significant *per se* performance for traits studied indicating that hybrid selection based on mean value would be worthy in sorghum.

## CONCLUSION

The present study estimated combining ability and heterosis for agronomic traits to identify promising sorghum hybrids for further selection and breeding. Parents ICSA 419 and ICSR 13031, were good general combiners with high *per se* performance for grain yield and many of the yield attributing traits. Sorghum hybrids such as ICSA 418 × ICSR 13025, ICSA 419 × ICSR 29 and ICSA 419 × ICSR 13004 were identified with suitable yield and component traits. These can be used in further breeding programs to develop high yielding cultivars.

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# INFLUENCE OF DIFFERENT DRIP IRRIGATION AND FERTIGATION LEVELS ON YIELD AND ECONOMICS OF HIGH DENSITY SUMMER SWEET CORN

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## ABSTRACT

An experiment was conducted to study the effect of different drip irrigation and fertigation levels on yield and economics of high-density sweet corn at College Farm, College of Agriculture, PJTSAU, Hyderabad, during summer 2020 and 2021. The experiment consisted of twelve treatments laid out in Factorial Randomized Block Design (FRBD) replicated thrice. Three irrigation levels (Irrigation scheduled at 0.6 [$I_1$], 0.8 [$I_2$] and 1.0 Epan [$I_3$] throughout the crop growth period) and four fertigation levels (application of 100% RDNK in differential dosage as per recommendation [$F_1$], application of 100% RDNK in differential dosage as per crop coefficient curve [$F_2$], application of 125% RDNK in differential dosage as per recommendation [$F_3$] and application of 125% RDNK in differential dosage as per crop coefficient curve [$F_4$] were included as treatments in this study. Among three irrigation levels, irrigation scheduled at 1.0 Epan recorded significantly higher gross returns, net returns and benefit cost ratio over 0.8 and 0.6 Epan during both the years and in means. Lowest gross returns, net returns and B:C ratio were observed under 0.6 Epan. Among the four fertigation levels, application of 125 % RDNK in differential dosage as per crop coefficient curve recorded significantly higher gross returns, net returns and B:C ratio which were on par with application of 125 % RDNK in differential dosage as per recommendation.

**Keywords:** Fertigation, gross returns, irrigation, net returns, sweetcorn

Maize (*Zea mays* L.) is called as "miracle crop" and also "queen of cereals" which is the world's widely grown cereal and primary staple food crop in many developing countries. The total area of maize in India is 9.56 million ha, with a production and productivity of 28.76 million tonnes and 3006 kg ha$^{-1}$, respectively (Directorate of economics and statistics, 2020-21). Telangana State contributed 0.56 million ha area with a production and productivity of 2.99 million tonnes and 5347 kg ha$^{-1}$ respectively in the year 2019-20 (Directorate of economics and statistics, 2019-20). 26.0 % of maize area in India is under irrigation whereas, in Telangana, 31.6 % of total maize area is under irrigation. (Directorate of Economics and Statistics, 2016-17). Sweet corn (*Zea mays* L. cv. Saccharata) is one type of maize which contains 13 to 15% sugar in immature grains. Sweet corn is a medium plant type and provides green ears in 65 to 85 days after sowing. The demand for sweet corn as a crunchy bite is increasing in and around cities in Telangana State. To sustain the cattle population in summer, sweet corn is a valuable supplementary source of green fodder. Being short duration in nature can fit into cropping system as second crop after long duration *kharif* crops like cotton, redgram etc., in summer under limited irrigation facilities. Optimum plant stand enhances the productivity of sweet corn by exploiting growth factors in an effective manner. At higher population levels, resources (water and nutrients) must be adequate to maintain uniform growth, development and grain yield. Drip irrigation is a highly efficient system which applies water directly in the root zone matching the crop water needs. Judicious use of irrigation water coupled with efficient nutrient management is more important to enhance total food grain production. Fertigation is the precise application of water-soluble fertilizers (Nitrogen and potassium) through drip irrigation directly to the active plant root zone. With the ease and simplicity of fertigation operation, application of fertilizers in shorter intervals through drip system is possible. It is logical to envisage that nutrient requirement of plant is not uniform throughout the season and it varies with its growth stage. With drip fertigation, it is possible to vary the quantity of fertilizers applied per fertigation event in accordance with plants fertilizer needs and loss of fertilisers through leaching can also minimised.

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Crop response may vary to different fertigation patterns and this needs careful investigations. Studies revealed that higher cob yield was recorded under fertigation given in differential dosage when compared to fertigation given in equal splits throughout the crop growth period (Jha *et al.* 2015). As 50% of density is increased against normal planting density (*i.e.* 83, 333 to 1,60,000), there is a need to revalidate fertilizer schedule of sweetcorn to achieve maximum yield potential from increased population. Though many studies were conducted on effect of drip irrigation and N fertigation levels on grain maize and sweetcorn, precise water as well as nutrients scheduling on scientific basis such as Kc values is not available in sweetcorn. With this background, a study was conducted with an objective to study the effect of different irrigation, fertigation levels and their interaction on yield and economics of high density summer sweet corn.

## MATERIAL AND METHODS

The present experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State. A field experiment was conducted during summer 2020 and 2021. The farm is geographically situated at an altitude of 542.3 m above mean sea level at $17^0 19'$ N latitude and $78^o 23'$ E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification. The mean weekly maximum temperature during cropping period ranged from 31.00 to 39.00$^0$C with an average of 34.31$^0$C in 2019-20 and 37.14 to 35.50$^0$C with an average of 30.63$^0$C in 2020-21, respectively. Whereas, the weekly mean minimum temperature varied between 10.64 to 24.29$^0$C with an average of 19.40$^0$C in 2019-20 and 11.21 to 16.21 with an average of 14.90$^0$C during 2020-21. During the crop growth period rainfall of 21.00 mm was received in five rainy days in 2019-20 and 4.6 mm in one rainy day in 2020-21. The mean weekly pan evaporation (PE) ranged from 3.74 to 7.90 mm in 2019-20 and 2.49 to 5.96 mm in 2020-21 respectively. The total evaporation during the crop study was 366.8 mm in 2019-20 and 335.5 mm during 2020-21. During both the years of study, the crop was largely raised under irrigation due to less quantity of rainfall received.

The soil of the experimental was sandy clay loam in texture (75.24 sand, 10.4% silt, and 14.06 % clay) with an average bulk density of 1.59 Mg m$^3$ for 0-60 cm depth and is slightly alkaline in reaction with pH ranging from 7.4 to 7.5 and Ec ranging from 0.26 to 0.28 (ds m$^{-1}$). The available N, P, and K were 182.4, 63.8, and 329.9 kg ha$^{-1}$. The experiment consisted of twelve treatments laid out in Factorial randomized block design (FRBD) and replicated thrice. Three irrigation levels (Irrigation scheduled at 0.6 [$I_1$], 0.8 [$I_2$] and 1.0 Epan [$I_3$], throughout the crop growth period) and four fertigation levels (100% RDNK in differential dosage as per recommendation [$F_1$], 100% RDNK in differential dosage as per crop coefficient curve [$F_2$], 125% RDNK in differential dosage as per recommendation [$F_3$] and 125% RDNK in differential dosage as per crop coefficient curve) [$F_4$], were included as treatments in this study. Sweet corn variety Madhuri was sown on 5$^{th}$ February, 2020 during first season and on 11$^{th}$ December, 2020 during second season by adopting a spacing of 30x20 cm. The recommended dose of fertilizer (RDF) 180, 60 and 50 kg N, $P_2O_5$, $K_2O$ ha$^{-1}$ respectively was applied in the form of urea, single super phosphate and sulphate of potash. A common dose of phosphorus was applied to the treatments as basal. Nitrogen and potassium were applied in splits through fertigation as per treatments.

Irrigation was scheduled at three days interval. The irrigation water was applied on the basis of pan evaporation (PE) data obtained from USWB open pan evaporimeter installed at the Agroclimatic Research Centre, ARI, Rajendranagar, Hyderabad. The quantity of applied water to each treatment was measured with the help of water meter. During rainy days, the volume of water applied to each treatment was adjusted for the effective rainfall received. The laterals of 16 mm diameter were laid at 0.6 m apart with spacing of 0.2 m distance between two inline emitters. The emitter discharge was 2.0 litres per hour. The application rate in drip irrigated treatments was calculated using following formula.

$$\text{Application rate (mm hr}^{-1}) = \frac{Q}{DL\,X\,DE}$$

Whereas

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

$D_L$ = Distance between lateral spacing (m)

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

Irrigation time for each treatment was calculated using following formulae.

$$\text{Irrigation time (minutes)} = \frac{Q}{DL \times DE}$$

**Table 1. Differential dosage of fertilizer application based on growth stage of sweet corn crop as per recommendation**

| Crop stage | Nutrient dose (kg ha$^{-1}$ day$^{-1}$) | |
|---|---|---|
| | N | $K_2O$ |
| After sowing 20 days (10-30 DAS) | 1.31 | 0.56 |
| Grand growth period 20 days (30-50 DAS) | 4.39 | 1.18 |
| Reproductive stage 20 days (50-70 DAS) | 3.30 | 0.75 |

Fertigation in 10 splits once in 6 days interval in differential dosage as per crop growth was carried out from 10 DAS to 70 DAS. For the treatments $F_1$ and $F_3$, fertigation was given in differential dosages as per recommendation as 100% and 125% RDF which was given in detail in Table 1. Whereas, for the treatments $F_2$ and $F_4$ fertigation was given in differential dosages as per crop coefficient curve as 100% and 125% RDF respectively which was given in Table 2. The fertigation pattern developed for sweet corn crop was given below.

**Table 2. Differential dosage of fertilizer application based on growth stage of sweet corn as per crop coefficient curve**

| Crop stage | Kc values | Nutrient dose (kg ha$^{-1}$ day$^{-1}$) | |
|---|---|---|---|
| | | N | $K_2O$ |
| 10-20 days | 0.4 | 1.54 | 0.42 |
| 21-26 | 0.51 | 2 | 0.53 |
| 27-31 | 0.62 | 2.4 | 0.65 |
| 32-37 | 0.74 | 2.8 | 0.77 |
| 38-43 | 0.84 | 3.2 | 0.88 |
| 44-49 | 0.90 | 3.5 | 0.95 |
| 50-55 | 0.98 | 3.8 | 1.03 |
| 56-61 | 1.05 | 4.03 | 1.10 |
| 62-67 | 1.13 | 4.3 | 1.18 |
| 68-70 | 1.15 | 4.4 | 1.20 |
| Average | 0.83 | | |

The crop was harvested on 24th April 2020 and 12th March 2021 during first and second seasons respectively. The prices of the inputs prevailed in local market during experimentation were considered for working out the cost of cultivation of sweet corn. The gross returns were calculated using the cob and green fodder yield of sweet corn and the market price of the produce at the time of marketing. The net returns per hectare were calculated by deducting the cost of cultivation per hectare from the gross returns per hectare.

Net monetary return = Gross monetary return - Total cost of cultivation

Benefit cost ratio = Gross returns (Rs ha$^{-1}$) / Cost of cultivation (Rs ha$^{-1}$)

The experimental data recorded on different parameters were analyzed statistically by applying the technique of analysis of variance for FRBD design and significance was tested by F-test. Critical difference for examining treatmental means for their significance was calculated at 5 per cent level of probability.

## RESULTS AND DISCUSSION

### Green cob yield (kg ha$^{-1}$)

Data presented in Table 3 indicated that, among the three irrigation regimes, drip irrigation scheduled at 1.0 Epan ($I_3$) has recorded significantly higher cob yield (12870, 12337 and 12604 kg ha$^{-1}$ during both the seasons and in means respectively) over other two irrigation levels ($I_2$ and $I_1$). While the lowest cob yield (9967, 9332 and 9650 kg ha$^{-1}$) was recorded under drip irrigation scheduled at 0.6 Epan ($I_1$).

The reason for higher cob yield in $I_3$ (1.0 Epan) can be attributed to favourable soil moisture conditions maintained throughout the crop growth period which enhanced the photosynthetic rate, biomass accumulation and partition into economic parts. The lowest yield under $I_1$ (0.6 Epan) might be due to the fact that moisture is not sufficient to absorb the nutrients by the crop as water is medium for nutrient absorption found to reduce leaf area, photosynthesis, biomass production and consequently cob yield. Robel *et al.* (2019), Brar *et al.* (2018), Bibe *et al.* (2017) and Kada Siddappa *et al.* (2013) and Islam *et al.* (2012) also reported higher yields under higher irrigation regimes.

Among four fertigation levels, 125% RDNK in differential dosage as per crop coefficient curve ($F_4$) registered significantly higher cob yield (12349, 11768 and 12059 kg ha$^{-1}$) over 100% RDNK in differential dosage as per recommendation ($F_1$) (10724, 10156 and 10440 kg ha$^{-1}$) and 100% RDNK in differential dosage as per crop coefficient curve ($F_2$) (11131, 10593

**Table 3. Green cob yield, green fodder yield (kg ha$^{-1}$) of sweet corn as influenced by different drip irrigation and fertigation levels**

| Treatments | Cost of cultivation (Rs ha$^{-1}$) | | | Gross returns (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | Means | 2020 | 2021 | Means |
| **Irrigation levels (I)** | | | | | | |
| $I_1$ | 9967 | 9332 | 9650 | 27878 | 26551 | 27215 |
| $I_2$ | 11734 | 11195 | 11465 | 33149 | 31559 | 32354 |
| $I_3$ | 12870 | 12337 | 12604 | 36409 | 35044 | 35727 |
| SEm± | 321 | 307 | - | 839 | 847 | - |
| CD (P=0.05%) | 941 | 899 | - | 2461 | 2485 | - |
| **Fertigation levels (F)** | | | | | | |
| $F_1$ | 10724 | 10156 | 10440 | 30117 | 28879 | 29498 |
| $F_2$ | 11131 | 10593 | 10862 | 31423 | 29937 | 30680 |
| $F_3$ | 11891 | 11300 | 11596 | 33600 | 32294 | 32947 |
| $F_4$ | 12349 | 11769 | 12059 | 34776 | 33096 | 33936 |
| SEm± | 371 | 354 | - | 969 | 978 | - |
| CD (P=0.05%) | 1087 | 1039 | - | 2842 | 2870 | - |
| **Interaction (IXF)** | | | | | | |
| SEm± | 642 | 613 | - | 1678 | 1695 | - |
| CD (P=0.05%) | NS | NS | - | NS | NS | - |

**Factor 1: Irrigation scheduling**

$I_1$: Drip irrigation 0.60 Epan throughout crop growth period

$I_2$: Drip irrigation 0.80 Epan throughout crop growth period

$I_3$: Drip irrigation 1.0 Epan throughout crop growth period

**Factor 2: Fertigation scheduling**

$F_1$: 100 % RDNK (differential dosage of N & K as per recommendation)

$F_2$: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)

$F_3$: 125 % RDNK (differential dosage of N & K as per recommendation)

$F_4$: 125 % RDNK (differential dosage of N & K as per crop coefficient curve)

and 10862 kg ha$^{-1}$) during both the years and in means. However, it was statistically at par with the application of 125% RDNK in differential dosage as per recommendation ($F_3$) (11891, 11300 and 10862 kg ha$^{-1}$ during both the years in means). While the lower fresh cob yield was recorded with the 100 % RDNK in differential dosage as per recommendation ($F_1$) during both the years. In particular, cob yield obtained through $F_1$ and $F_2$ were at par with each other and cob yield obtained with $F_3$ was also comparable to $F_2$ but was statistically higher over $F_1$. Where in 25% of the nutrients can be saved with recommendation based sustainable approach like crop coefficient curve.

The higher yield recorded with 125% RDNK in differential dosage as per crop coefficient curve ($F_4$) might be due to lower rates of fertilizer during initial stages and higher rates of fertilizer at grand growth period and reproductive stage met the crop growth needs which made the crop to uptake more nutrients thereby resulting in higher cob yield. In this way

**Table 4a. Economics of sweet corn as influenced by different drip irrigation and fertigation levels**

| Treatments | Green cob yield (kg ha$^{-1}$) | | | Green fodder yield (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | Means | 2020 | 2021 | Means |
| **Irrigation levels (I)** | | | | | | |
| $I_1$ | 44747 | 48126 | 46436 | 127550 | 119871 | 123710 |
| $I_2$ | 45763 | 48776 | 47269 | 150484 | 143509 | 146996 |
| $I_3$ | 46781 | 49581 | 48181 | 165108 | 158410 | 161759 |
| SEm± | - | - | - | 3319 | 3316 | - |
| CD (P=0.05%) | - | - | - | 9736 | 9725 | - |
| **Fertigation levels (F)** | | | | | | |
| $F_1$ | 44092 | 46939 | 45516 | 137354 | 130444 | 133899 |
| $F_2$ | 44092 | 46939 | 45516 | 142730 | 135864 | 139297 |
| $F_3$ | 47435 | 50717 | 49076 | 152508 | 145297 | 148902 |
| $F_4$ | 47435 | 50717 | 49076 | 158266 | 150783 | 154524 |
| SEm± | - | - | - | 3833 | 3829 | - |
| CD (P=0.05%) | - | - | - | 11242 | 11230 | - |
| **Interaction (IXF)** | | | | | | |
| SEm± | 642 | 613 | - | 6639 | 6632 | - |
| CD (P=0.05%) | NS | NS | NS | NS | NS | - |

**Factor 1: Irrigation scheduling**

$I_1$: Drip irrigation 0.60 Epan throughout crop growth period

$I_2$: Drip irrigation 0.80 Epan throughout crop growth period

$I_3$: Drip irrigation 1.0 Epan throughout crop growth period

**Factor 2: Fertigation scheduling**

$F_1$: 100 % RDNK (differential dosage of N & K as per recommendation)

$F_2$: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)

$F_3$: 125 % RDNK (differential dosage of N & K as per recommendation)

$F_4$: 125 % RDNK (differential dosage of N & K as per crop coefficient curve)

nutrients were supplied more precisely and scientifically under $F_4$ and $F_2$ treatments when compared to $F_1$ and $F_3$ treatments. The higher cob yield under $F_3$ and $F_4$ fertigation levels over $F_1$ and $F_2$ was also due to increase in fertilizer levels (N and K) attributed to adequate nutrient supply under higher density planting, which in turn improved all growth and yield attributing characters. Similar findings of increase in the yield with the increase in the fertilizer rates were also reported by Richa Khanna (2013), Sharana Basava (2012) and Shiva Kumar (2011).

**Green fodder yield (kg ha$^{-1}$)**

A scrutiny of data (Table 3) indicated that irrigation scheduled at 1.0 Epan ($I_3$) registered significantly higher green fodder yield (36409, 35044 and 35727 kg ha$^{-1}$) over 0.8 Epan ($I_2$) (33149, 31559 and 32354 kg ha$^{-1}$) and 0.6 Epan ($I_1$) (27859, 26551 and 27215 kg ha$^{-1}$) during both the years and in means. While the fodder yield recorded under 0.6 Epan ($I_1$) remained significantly inferior to 0.8 Epan ($I_2$) and 1.0 Epan ($I_3$) during both the seasons and in means. Lower fodder yield under 0.6 Epan ($I_1$) might be due to moisture stress conditions that resulted in reduced cell expansion, photosynthetic leaf area, reducing the crop growth and total dry matter accumulation. The optimum quantity of water at desired depth leads to minimizing of stress felt by the crop and helped in realizing higher fodder yield under $I_3$ irrigation level. Sharana Basava (2012) also found maximum green fodder yield under drip irrigation scheduled at 100% Epan over 60 and 80% Epan. Similar findings were also reported by Bibe *et al.* (2017), Kada Siddappa *et al.* (2013) and Shiva kumar *et al.* (2011).

Among fertigation levels, significantly higher green fodder yield (34776, 33096 and 33936 kg ha$^{-1}$) was realised with the 125% RDNK in differential dosage as per crop coefficient curve ($F_4$) over 100% RDNK in differential dosage as per recommendation ($F_1$) (30117, 28879 and 29498 kg ha$^{-1}$) and 100% RDNK in differential dosage as per crop coefficient curve ($F_2$) (31423, 29937 and 30680 kg ha$^{-1}$) and was statistically on par with the fodder yield obtained with the 125% RDNK in differential dosage as per recommendation ($F_3$) (33600, 32294 and 32947 kg ha$^{-1}$) during both the years and in means. While $F_1$ recorded lower green fodder yield during both the years and in means which was on par with $F_2$. Further, $F_3$ produced green fodder yield which was on par with $F_2$ and was statistically higher over $F_1$. In this study, among the two fertigation patterns i.e $F_1$, $F_3$ and $F_2$, $F_4$ the nutrients were supplied more precisely to the crop under $F_2$, $F_4$ patterns i.e the quantity of fertilizers applied per fertigation event were in accordance with plants nutrient needs and resulted in higher dry matter production thus resulting in higher fodder yield when compared to other fertigation pattern ($F_1$, $F_3$). Higher yield with the application of 125% RDNK over 100% RDNK in both the fertigation patterns was due to higher availability of all the two major nutrients (N and k) in the soil solution which led to higher uptake and better crop growth which also gave maximum plant height, LAI and ultimately produced more biological yield. Similarly, Sharana Basava (2012), Fanish *et al.* (2011) also recorded higher fodder yield under increased levels of fertilisers.

## Economics

Cost of cultivation varied of sweetcorn for different treatments from Rs. 44092 to 47435 ha$^{-1}$ during 2020 and Rs. 46939 and 50717 during 2020 (Table 4a) in different treatments of sweetcorn crop.

**Table 4b. Economics of sweet corn as influenced by different drip irrigation and fertigation levels**

| Treatments | Net Returns (kg ha$^{-1}$) | | | Benefit Cost Ratio | | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | Means | 2020 | 2021 | Means |
| **Irrigation levels (I)** | | | | | | |
| $I_1$ | 82803 | 71745 | 77274 | 2.9 | 2.5 | 2.7 |
| $I_2$ | 104721 | 94733 | 99727 | 3.3 | 2.9 | 3.1 |
| $I_3$ | 118327 | 108829 | 113578 | 3.5 | 3.2 | 3.4 |
| SEm± | 3319 | 3316 | - | 0.04 | 0.03 | - |
| CD (P=0.05%) | 9736 | 9725 | - | 0.12 | 0.10 | - |
| **Fertigation levels (F)** | | | | | | |
| $F_1$ | 93262 | 83505 | 88383 | 3.1 | 2.8 | 3.0 |
| $F_2$ | 98638 | 88925 | 93782 | 3.2 | 2.9 | 3.1 |
| $F_3$ | 105072 | 94580 | 99826 | 3.2 | 2.9 | 3.1 |
| $F_4$ | 110830 | 100066 | 105448 | 3.3 | 3.0 | 3.2 |
| SEm± | 3833 | 3829 | - | 0.05 | 0.04 | - |
| CD (P=0.05%) | 11242 | 11230 | - | 0.14 | 0.12 | - |
| **Interaction (IXF)** | | | | | | |
| SEm± | 6639 | 6632 | - | 0.08 | 0.07 | - |
| CD (P=0.05%) | NS | NS | - | NS | NS | - |

**Factor 1: Irrigation scheduling**

$I_1$: Drip irrigation 0.60 Epan throughout crop growth period

$I_2$: Drip irrigation 0.80 Epan throughout crop growth period

$I_3$: Drip irrigation 1.0 Epan throughout crop growth period

**Factor 2: Fertigation scheduling**

$F_1$: 100 % RDNK (differential dosage of N & K as per recommendation)

$F_2$: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)

$F_3$: 125 % RDNK (differential dosage of N & K as per recommendation)

$F_4$: 125 % RDNK (differential dosage of N & K as per crop coefficient curve)

Main variation in cost of cultivation was due to fertigation levels of N & $K_2O$, cost of water, fertilizers and man power required for irrigation, fertigation and other operations among treatments. Results showed that among irrigation levels highest cultivation cost (Rs. 46781, 49581 and 48181 $ha^{-1}$) incurred with irrigation scheduled at 1.0 Epan ($I_3$) when compared to other irrigation regimes ($I_2$ and $I_1$) during 2020, 2021 and in means. Among different fertigation levels cost of cultivation was higher (Rs. 47435, 50717 and 49076 $ha^{-1}$) with application of 125% RDNK as per crop coefficient curve ($F_4$) and application of 125% RDNK as per recommendation ($F_3$) when compared to application of 100% RDNK as per crop coefficient curve ($F_2$) and application of 100% RDNK as per recommendation ($F_1$).

Results presented in Table 4a and 4b revealed that, significantly higher gross returns (Rs.1,65,108, 158410 and 161759 $ha^{-1}$), net returns (Rs.1,18,327, 108829 and 113578 $ha^{-1}$) and B:C ratios (3.5, 3.2 and 3.4) were realised from drip irrigation scheduled at 1.0 Epan ($I_3$) when compared to 0.8 Epan and 0.6 Epan ($I_2$ and $I_1$) during both the seasons and in means. While, lower gross returns (Rs.127550, 119871 and 123710 $ha^{-1}$), net returns (Rs. 82803, 71745 and 77274 $ha^{-1}$) and B:C (2.9, 2.5 and 2.7) ratios were recorded with drip irrigation at 0.6 Epan during 2020, 2021 and in means. Increased gross returns, net returns and B:C ratio with ($I_3$) was mainly due to high cob and fodder yield obtained when compared to other treatments ($I_2$ and $I_1$). These results were in similarity with the Brar *et al.* (2018), Yash Pal (2016) and Sharana Bhasava (2012) with regard to higher gross and net returns with higher drip irrigation levels.

Among four fertigation levels, gross returns (Rs.158266, 150783 and 154524 $ha^{-1}$), net returns (Rs.110830, 100036 and 105448 $ha^{-1}$) and B:C ratio (3.3, 3.0 and 3.2) were significantly higher with application of 125% RDNK in differential dosage as per crop coefficient curve ($F_4$) over application of 100% RDNK in differential dosage as per crop coefficient curve ($F_2$) and application of 100% RDNK in differential dosage as per recommendation ($F_1$) and was on par with application of 125% RDNK in differential dosage as per recommendation ($F_3$) during 2020, 2021 and in means. While lower gross returns (Rs.137354, 130444 and 133899 $ha^{-1}$), net returns (Rs. 93262, 83505 and 88383 $ha^{-1}$) and B:C ratios (3.1, 2.8 and 3.0) were obtained from $F_1$ which were on par with $F_2$. The higher gross returns, net returns and B:C ratio under $F_3$, $F_4$ was due to higher fresh cob and green fodder yield obtained over other fertigation levels. Shruthi *et al.* (2018) and Richa Khanna (2013) also recorded higher gross returns, net returns and B:C ratio under higher fertigation levels. While the gross returns, net returns and B:C ratio obtained from $F_3$ were also comparable with the $F_2$ during both the years of study and on means.

However, there was no significant interaction effect between different drip irrigation and fertigation levels on yield and economics of sweet corn during both the seasons and in means.

## CONCLUSION

Based on the results obtained in the present investigation, it is concluded that the high density sweet corn crop grown with drip irrigation scheduled at 1.0 Epan and fertigation at 125 % RDN and K in differential dosage as per crop coefficient curve during summer under semi arid conditions can be recommended for realizing better cob yield, green fodder yield and returns. Further the yield and net returns obtained with the fertigation at 100% RDN and K in differential dosage as per crop coefficient curve was comparable with the yield produced with the fertigation at 125% RDN and K in differential dosage as per recommendation which shows that 25% of the fertilizers can be saved if the fertilizers are provided to the crop according to the crop growth needs in a precise manner.

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# DIVERSITY AND SEASONAL ABUNDANCE OF PREDATORY SPIDER FAUNA IN PADDY ECOSYSTEM

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## ABSTRACT

A field experiment was conducted during *kharif* 2019 to study the dynamics and diversity of spiders in paddy ecosystem at Rajendranagar, Telangana. A total of 22 spider species were documented belonging to 11 families and 20 genera. Out of 22 species 6 species were dominant *viz., Pardosa pseudoannulata*, *Chrysso sp.*, *Tetragnatha mandibulata*, *T. elongata*, *Lycosa pseudoannulata, Leucage sp.*; 15 species were sub-dominant *viz., Runcinia grammica*, *Heteropoda venatoria*, *Arctosa maculata*, *Araneus inustus*, *Argiope anasuja*, *Zygiella notata*, *Z. indica*, *Chieranthium sp.*, *Agelenopsis sp.*, *Atypena formosana*, *Hamataliwa sp., Oxyopes salticus*, *Bianor aurocinctus*, *Evarcha falcata*, *Mymarachne sp.* and one species was satellite *i.e., Neoscona theisi*. Among all species *P. pseudoannulata* was most dominant and *N. theisi* was scarce. Of all families recorded, Tetragnathidae was predominant, while Linyphiidae was least representative of total spider population in experimental plot. Density, Shannon-Weiner index (H'), Simpson's diversity index (ë), Margalef richness index (D) and Pielou's evenness index (J) ranged from 0.30 to 7.90 sq. m, 1.10 to 2.84, 0.83 to 1.00, 1.82 to 6.79 and 0.35 to 0.91, respectively, indicating that spider fauna in paddy ecosystem were moderately diverse and evenly distributed. The highest diversity was recorded during reproductive stage of crop *i.e.,* 36 to 40 Standard meteorological weeks (SMW) during high pest density, suggesting paddy ecosystem of Rajendranagar could be pronounced to be a stable ecosystem with moderate diversity of spiders.

**Keywords:** Diversity, lycosidae, simpson index, spider richness, tetragnatha

Rice (*Oryza sativa*) is the world's second most important cereal staple food crop among the three leading food crops of the world, with maize and wheat being the other two, providing food to almost half of the world population. India is an important centre of rice cultivation among top ten rice producing countries in the world. The highest rice producing state in India is West Bengal followed by Punjab, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Telangana, Bihar, Chhattisgarh and Orissa. All these states together account for almost 72 per cent of the total area under paddy and contribute to almost 75 per cent of the total production in the country. Telangana produced 6.25 Mt from an area of 1.27 M.h with productivity of 3176 kg $ha^{-1}$ in 2017-18. Rice is one of the major crops in the state grown in all districts *viz.,* Adilabad, Karimnagar, Khammam, Nizamabad, Warangal, Nalgonda, Medak and Mahabubnagar (Agricultural Statistics at a Glance, 2018).

Among the various yield constraints in paddy production, the insect pests are of prime importance and are estimated to cause yield loss up to 30-70 per cent depending upon the severity of incidence. Almost 20 insects are considered as major insect pests of economic importance which include stem borers, gall midge, defoliators and vectors like leafhoppers and plant hoppers that cause direct damage and transmit various diseases (Pathak and Dhaliwal, 1981). The increased awareness on the deleterious side effects due to the intense use of pesticides for the pest control brought universally accepted concept "Integrated Pest Management". Among the IPM strategies, use of natural enemies *viz.,* parasitoids, predators and pathogens play an important role in regulating the populations. About 40 to 60 per cent of the pests in paddy are controlled by their natural enemies (Swaminathan and Siddiq, 1991). In a stable ecosystem, the natural enemies particularly predatory spiders have been recorded as potential weapon to regulate the paddy insect pests. Spiders are the largest group of arachnids belonging to class Arachnida and order Araneae, comprising 49,556 species from 129 families and 4,219 genera (World spider catalog, 2021). They are well adapted to certain habitats because of their ability to withstand periods of low food availability and also to take advantage of periods of prey-abundance. Spiders are also recognized as potential predators in biological pest suppression, being able

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to kill large number of insects per unit time, with good searching ability, wide host range, adaptation under food constraints, low metabolic rate, ease in multiplication and polyphagous nature enabled with energy conservation mechanism (Rajeswaran *et al*., 2005). Despite having such dependable attributes, their role in pest control and crop protection has not been utilized properly in India. Major gap still exists in our knowledge of the biodiversity of spiders in many areas within varied ecosystems of India. Spiders are an important but poorly studied group of arthropods despite their significant role in the regulation of insect pests and other invertebrate populations in most ecosystems. Hence, the present study was undertaken in paddy ecosystem.

**MATERIAL AND METHODS**

An experiment was conducted at Rice Research Centre, Agricultural Research Institute, Rajendranagar to study the abundance of spider fauna. The rice fields of rice section, ARI, Rajendranagar were selected for collection of data. The spider populations were collected from 10 quadrates (1×1m) at fortnightly intervals from $30^{th}$ to $47^{th}$ SMW through direct count method during *kharif* 2019. The spiders with distinct size/colour/web were collected initially within the quadrate during data recording. Later each plant was searched for spiders from top to the bottom of leaves/other plant parts. Five pit fall traps on each border (20 per field) were installed and spiders trapped were collected. Spiders collected at fortnight intervals and trapped in pitfall traps were brought to laboratory for identification and to study their diversity. To quantify the diversity of spiders collected from paddy ecosystem diversity indices such as species richness, species diversity, species evenness and density were developed.

**Diversity indices:** The diversity of spiders in paddy ecosystem was analyzed by employing different indices *viz.,* the Shannon-Wiener index, Simpson index, Pielou's Evenness Index and Margalef richness index (D).

**Shannon-Wiener diversity index (H):** Shannon-Weiner index (H') measures the degree of uncertainty in predicting the species in a random sample and is related to the diversity of a community. If a community has low diversity (dominated by one species), the uncertainty of prediction is low. Therefore, in Shannon-Wiener index, the increasing values represent an increase in the diversity of species.

$$H = \sum_{i=1}^{k} pi\ 1n\ pi$$

Where, Pi = fi/n = proportion of $i^{th}$ species in the total sample, n = Total number of specimens in the sample, fi = number of the specimens of the species, k = total number of species, In = natural logarithm ($log_e$)

**Simpson's diversity index ( $\lambda$ ):** Simpson's diversity index is a measure of diversity which takes into account the number of species present and relative abundance of each species. As species richness and evenness increases diversity increases.

$$\lambda = \frac{\sum ni\ (ni-1)}{N(N-1)}$$

Where, $n_i$ = the number of individuals of species

N = total number of organisms of all species

**Margalef richness index (D):** The Margalef index is a species richness index and computed based on the relationship between species richness (S) and total number of individuals observed (N). The Margalef index is sensitive to sample size, which increases with increasing sample size.

$$D = \frac{S-1}{1nN}$$

Where, S = number of species or genera collected (Species richness)

N = total number of individuals collected

**Pielou's Evenness Index (J) or Equitability (E):** The species evenness index is a measure of how evenly species are distributed in a sample. When all species in a sample are equally abundant an evenness index will be at its maximum and decreasing towards zero as the relative abundance of the species diverges away from evenness. The value of 'J' range from '0' to '1'. Pielou's Evenness Index (J) or equitability (E) was calculated using the following formula.

$$J = \frac{H'}{Ln(S)\,or\,H'}$$

Where, H' = Species diversity,

Ln (S) = Natural logarithm of the number of species in a sample, across all samples in dataset

**Table 1. Relative species abundance and dynamics of spider fauna in rice ecosystem during *kharif* 2019**

| Guild Structure | Family | SMW / Species | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | Total (n)/ All SMW | Relative species abundance | Species category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambushers | Thomisidae | *Runcinia grammica* | 0 | 0 | 1 | 2 | 2 | 3 | 1 | 0 | 0 | 9 | 2.9 | SD |
| Foliage runners | Sparassidae | *Heteropoda venatoria* | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 0 | 6 | 1.9 | SD |
| Ground runners | Lycosidae | *Arctosa maculata* | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 6 | 1.9 | SD |
| | | *Lycosa pseudoannulata* | 0 | 1 | 3 | 3 | 4 | 5 | 0 | 0 | 0 | 16 | 5.1 | D |
| | | *Pardosa pseudoannulata* | 1 | 4 | 5 | 7 | 8 | 9 | 10 | 6 | 4 | 54 | 17.3 | D |
| Orb weaver | Araneidae | *Araneus inustus* | 0 | 0 | 1 | 2 | 2 | 3 | 0 | 0 | 0 | 8 | 2.6 | SD |
| | | *Argiope anasuja* | 0 | 0 | 0 | 1 | 2 | 4 | 2 | 2 | 3 | 14 | 4.5 | SD |
| | | *Neoscona theisi* | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0.6 | Satellite |
| | | *Zygiella notata* | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 7 | 2.2 | SD |
| | | *Zygiella indica* | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 5 | 1.6 | SD |
| | Tetragnathidae | *Leucage sp.* | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 4 | 3 | 16 | 5.1 | D |
| | | *Tetragnatha mandibulata* | 1 | 3 | 5 | 6 | 6 | 10 | 8 | 5 | 4 | 48 | 15.4 | D |
| | | *Tetragnatha elongata* | 0 | 1 | 3 | 4 | 3 | 4 | 2 | 0 | 0 | 17 | 5.4 | D |
| Sac web builders | Cheiracanthidae | *Chieranthium sp.* | 0 | 0 | 0 | 1 | 2 | 3 | 1 | 0 | 0 | 7 | 2.2 | SD |
| Sheet web builders | Agelenidae | *Agelenopsis sp.* | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 5 | 1.6 | SD |
| | Linyphidae | *Atypena formosana* | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 1.3 | SD |
| Space Web builders | Therididae | *Chrysso sp.* | 1 | 4 | 6 | 7 | 7 | 9 | 8 | 5 | 4 | 51 | 16.3 | D |
| Stalkers | Oxyopidae | *Hamataliwa sp.* | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 5 | 1.6 | SD |
| | | *Oxyopes salticus* | 0 | 0 | 1 | 2 | 4 | 2 | 2 | 0 | 0 | 11 | 3.5 | SD |
| | Salticidae | *Bianor aurocinctus* | 0 | 1 | 3 | 4 | 3 | 2 | 0 | 0 | 0 | 13 | 4.2 | SD |
| | | *Evarcha falcata* | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 5 | 1.6 | SD |
| | | *Mymarachne sp.* | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 3 | 1.0 | SD |
| | Total (N) | | 3 | 14 | 30 | 48 | 58 | 76 | 42 | 23 | 18 | 312 | | |

D = Dominant species, SD = Sub-dominant species, SMW = Standard Meteorological Week

**Density**: Density was calculated using the following formula

$$\text{Density} = \frac{\text{No.of spider observed}}{\text{No.of quadrants}}$$

**Relative abundance:** Relative abundance is the per cent composition of an organism of particular kind relative to the total number of organisms in the area. The spider species were classified into following categories based on relative abundance *viz.,* < 1 per cent satellite species; 1-5 per cent sub-dominant and > 5 per cent dominant. Relative abundance was calculated using the following formula given by Whittaker, 1972.

$$\text{Relative abundance (\%)} = \frac{1\text{si}}{\sum \text{Nsi}} \text{x} 100$$

Where, Isi = Total number of individual species

$\sum$Nsi = Total number of species population

## RESULTS AND DISCUSSION

The data collected on the abundance of spider fauna at fortnightly intervals throughout the crop season from transplanting to the harvest of the crop was subjected to different diversity indices for every fortnight to find out dynamics of spider population.

### Population dynamics of spider fauna in rice ecosystem

A total of 237 (Table 1) spiders were collected, identified and classified into eight guilds on the basis of mode of predation or attack on the prey *viz.,* 1) ambushers consisting of genera of family Thomisidae, 2)foliage runners made up of genera of family Sparassidae, 3) ground runners comprising of genera of family Lycosidae, 4) orb weavers consisting of genera of families Araneidae and Tetragnathidae, 5) sac web builders consisting of genera of family Cheiracanthidae, 6) sheet web builders comprising of genera of family Agelenidae and Linyphiidae, 7) space web builders consisting of genera of families of Theridiidae and 8) stalkers made up of genera of families Salticidae and Oxyopidae. The orb weavers constituted 37.5 per cent of the population, while ground runners comprised 24.4 per cent, space web builders 16.3 per cent, stalkers 11.9 per cent, ambushers and sheet web builders 2.9 per cent each, sac web builders 2.2 per cent and foliage runners 1.9 per cent (Figure 1).

Majority of spiders collected from paddy ecosystem belonged to family Tetragnathidae (26%)

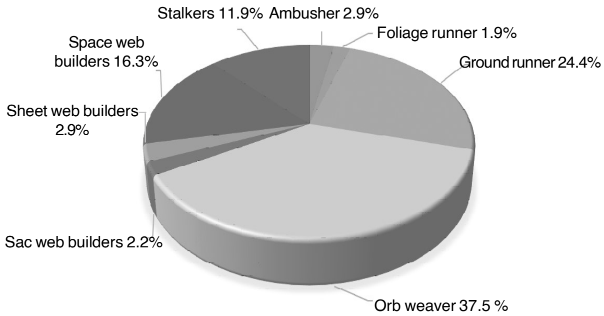


**Figure 1. Percent composition of spider guild structure in rice ecosystem during *kharif* 2019**

followed by Lycosidae (24.4%), Therididae (16.3%), Araneidae (11.5%), Salticidae (6.7%), Oxyopidae (5.1%), Thomisidae (2.9 %), Cheiracanthidae (2.2 %), Sparassidae (1.9%), Agelenidae (1.6%) and Linyphiidae (1.3%) (Figure 2). Tetragnathidae was the dominant family while Linyphiidae was least representative of the total population collected during the crop period. Twenty two spider species were recorded belonging to 20 genera and 11 families *viz.,* Thomisidae, Sparassidae, Lycosidae, Araneidae, Tetragnathidae, Cheiracanthidae, Agelenidae, Linyphidae, Therididae, Oxyopidae and Salticidae. Araneidae comprised of four genera *viz., Araneus*, *Argiope*, *Neoscona* and *Zygiella*, Salticidae and Lycosidae consisted of three genera each. *Bianor*, *Evarcha* and *Mymarachne* belonged to Salticidae, while *Pardosa*, *Lycosa* and *Arctosa* to Lycosidae, Tetragnathidae and Oxyopidae represented two genera each. *Tetragnatha* and *Leucauge* belonged to Tetragnathidae and *Hamataliwa* and *Oxyopes* to Oxyopidae. Theridiidae was represented by *Chrysso*, Thomisidae by *Runcinia*, Cheiracanthidae by *Cheiracanthium*, Sparassidae by *Heteropoda*, Agelenidae by *Agelenopsis* and Linyphiidae by genus *Atypena*. The various species recorded under different families are given in Table 1 and Figure 3.

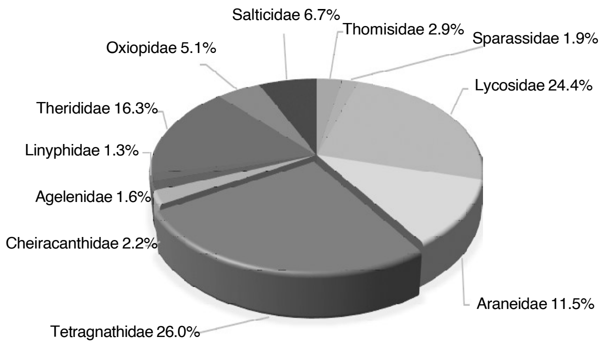


**Figure 2. Percent composition of spider families in rice ecosystem during *kharif* 2019**

**Thomisidae**: The family documented single species *R. grammica* (n=9). The species occurred from 34th standard week (second fortnight of August) to 42nd standard week (second fortnight of October). Peak abundance was recorded during 40th SMW *i.e.,* during the month of October.

**Sparassidae:** Members of this family were categorized as foliage runners and comprised of single species *Heteropoda venatoria* (n=6). The species occurred from 36th SMW (first fortnight of September) to 44th SMW with peak abundance during 40th SMW (Second fortnight of November).

**Lycosidae:** Members of this family were categorized as ground runners. Lycosidae were recorded with three species belonged to three genera *viz., Arctosa*, *Lycosa* and *Pardosa*. *P. pseudoannulata* was recorded throughout crop period from transplanting to harvesting *i.e.,* 30th to 46th SMW, whereas *L. pseudoannulata* occurred from 32nd to 40th SMW and *A. maculata* from 36th to 40th SMW. Peak abundance of *A. maculata* and *L. pseudoannulata* were recorded during 40th SMW and *P. pseudoannulata* during 42nd SMW, respectively.

**Araneidae:** Members of this family were grouped under orb weavers with five species which belonged to four genera *viz., Zygiella*, *Araneus*, *Argiope* and *Neoscona*. *Z. notata* (n=7) was recorded during two standard weeks only *viz.,* 38th and 40th SMW, whereas *Z. indica* (n=5) during 36th to 40th SMW. *A. anasuja* (n =14) was recorded from 36th SMW to 46th SMW with peak abundance in 40th SMW. *A. inustus* (n=8) occurred from 34th to 40th SMW. *N. theisi* was the least represented species (n=2), which recorded during two standard weeks *viz.,* 36th and 38th SMW. Peak abundance of all documented species of the Araneidae were recorded during 40th SMW except *N. theisi*.

**Tetragnathidae:** Tetragnathidae was the largest family of the total population and classified under orb weavers. The three species collected belonged to two genera *viz., Leucage* and *Tetragnatha*. *T. elongata* (n= 17) occurred from 32nd to 42nd SMW with peak abundance during 36th and 40th SMW, while *T. mandibulata* (n=48) was the predominant species and recorded throughout crop period from transplanting to harvesting *i.e.,* 30th to 46th SMW with peak abundance during 40th SMW. *Leucage* (n=16) occurred from reproductive to harvesting stage *i.e.,* 38th to 46th SMW with peak abundance during 42nd SMW.

**Cheiracanthidae:** Cheiracanthidae was categorized as sac web builders with single species *Cheiracanthium sp.* (n=7) which occurred from 36th to 42nd SMW with peak abundance during 40th SMW.

**Agelenidae:** Agelenidae grouped under sheet web builders recorded single species *Agelenopsis sp.* (n=5) from 36th to 42nd SMW with peak abundance during 40th SMW.

**Linyphidae:** Linyphidae was the least represented family of paddy ecosystem with single species *Atypena formosana* (n=4) recorded from 38th to 42nd SMW with peak abundance during 40th SMW.

**Therididae:** Therididae was one of the largest family recorded after Tetragnathidae and Lycosidae with single species *Chrysso sp.* (n=51) classified as space web builders. The species occurred throughout crop period from 30th SMW to 46th SMW with peak abundance during 40th SMW.

**Oxyopidae:** Oxyopidae recorded two species belonged to two genera *Hamataliwa* and *Oxyopes* under stalkers. The abundance of *Hamataliwa sp.* (n=5) occurred from 34th to 40th SMW with peak abundance during 40th SMW and *O. salticus* (n=15) from 34th to 42nd SMW with peak abundance during 38th SMW.

**Salticidae:** Salticidae also categorized as stalkers with three species belonging to three genera *viz., Bianor*, *Evarchala* and *Mymarachne*. *B. aurocinctus* occurred from 32nd to 40th SMW, *E. falcata* from 34th to 40th SMW and *Mymarachne sp.* from 36th to 40th SMW. Peak abundance of *B. aurocinctus* and *E. falcata* was recorded during 36th SMW.

The overall abundance of spider species in paddy ecosystem were in the following descending order: *P. pseudoannulata* > *Chrysso sp.* > *T. mandibulata* > *T. elongata* > *L. pseudoannulata* > *Leucage sp.* > *A. anasuja* > *B. aurocinctus* > *O. salticus* > *R. grammica* > *A. inustus* > *Z. notata* > *Cheiracanthium sp.* > *H. venatoria* > *A. maculata* > *Z. indica* > *Agelenopsis sp.* > *Hamataliwa sp.* > *E. falcata* > *A. formosana* > *Mymarachne sp.* > *N. theisi.*

**Density of spider fauna in rice ecosystem**

The density of spiders varied from 0.30 to 7.90 per quadrate (sq. m) during entire crop period. Density of spiders recorded in different meteorological weeks were 0.30, 1.80, 3.0, 4.20, 5.70, 7.80, 7.90, 5.80 and

**Table 2. Diversity and richness of spider fauna in rice ecosystem during *kharif* 2019**

| SMW | No. of species recorded | Species diversity indices | | | | |
|---|---|---|---|---|---|---|
| | | Shannon-Weiner index (H) | Simpson's Diversity index ( λ ) | Margalef index (D) | Pielous' s eveness index (J) | Density /Sq. m |
| 30 | 3 | 1.10 | 1.00 | 1.82 | 0.35 | 0.30 |
| 32 | 6 | 1.61 | 0.84 | 2.79 | 0.51 | 1.80 |
| 34 | 11 | 1.95 | 0.90 | 4.17 | 0.62 | 3.00 |
| 36 | 19 | 2.66 | 0.93 | 6.11 | 0.85 | 4.20 |
| 38 | 22 | 2.85 | 0.94 | 6.79 | 0.91 | 5.70 |
| 40 | 21 | 2.84 | 0.94 | 6.57 | 0.91 | 7.80 |
| 42 | 12 | 2.11 | 0.87 | 4.43 | 0.67 | 7.90 |
| 44 | 6 | 1.67 | 0.83 | 2.79 | 0.53 | 5.80 |
| 46 | 5 | 1.60 | 0.84 | 2.49 | 0.51 | 3.10 |

3.10 per quadrate in 30$^{th}$, 32$^{nd}$, 34$^{th}$, 36$^{th}$,38$^{th}$, 40$^{th}$, 42$^{nd}$, 44$^{th}$ and 46$^{th}$ standard weeks, respectively. Lowest number of spider density was recorded at transplanting *i.e.,* 0.30 per quadrate in 30$^{th}$ meteorological week, thereafter population gradually increased up to 42$^{nd}$ meteorological week *i.e.,* 7.90 per sq. m (Table 2 and Figure 4), increasing with prey density and thereafter the population started decreasing up to harvest *i.e.,* 46$^{th}$ meteorological week. Highest number of spiders 7.90 per sq. m were recorded in the month of October *i.e.,* at the reproductive stage of the crop when maximum temperature was 32.1$^0$C, minimum temperature 18.4$^0$C, relative humidity 89.7 and 46.7 per cent at 7 am and 2 pm, respectively and rainfall 43.2 mm.

**Shannon-Weiner index (H'):** Shannon-Weiner index (H') of study period ranged from 1.10 to 2.84 in paddy ecosystem during the year 2019 indicating that the ecosystem had moderate diversity of spiders. The diversity indices were recorded as 1.10, 1.61, 1.95, 2.66, 2.85, 2.84, 2.11, 1.67 and 1.60 during 30$^{th}$, 32$^{nd}$, 34$^{th}$, 36$^{th}$, 38$^{th}$, 40$^{th}$, 42$^{nd}$, 44$^{th}$ and 46$^{th}$ standard weeks, respectively (Table 1 and Figure 4). The diversity of spiders was lowest during transplanting stage and gradually increased up to reproductive stage, thereafter decreased till harvesting. Lowest diversity 1.10 was recorded in 30$^{th}$ standard week and highest at 2.85 during 38$^{th}$ standard week when the pest incidence was high. Diversity was more during the month of October and September but lowest during July and November. A higher Shannon-Wiener index indicating a higher diversity of spiders indicating lesser competition between the species for the food resources as spider genera vary with each other in terms of food preferences. Such a variation keeps up the chances of enhanced natural control.

**Simpson's (D):** Simpson's diversity index ranged from 0.83 to 1.00 during period of study in rice ecosystem, which indicated that spiders were moderately diverse. The diversity indices recorded were 1.00, 0.84, 0.90, 0.93, 0.94, 0.94, 0.87, 0.83 and 0.84 during 30$^{th}$, 32$^{nd}$, 34$^{th}$, 36$^{th}$, 38$^{th}$, 40$^{th}$, 42$^{nd}$, 44$^{th}$ and 46$^{th}$ standard weeks, respectively. A diverse community indicates more complicated food chain, better flow of energy between the various trophic levels and enhanced stability. Thus, rice ecosystem of Rajendranagar could be pronounced to be a stable ecosystem with moderate diversity of spiders.

**Spider richness:** Margalef index was used to measure species richness. It depends on sample size and greater the sampling size potentially higher is the index value. Margalef richness index (d) ranged from 1.82 to 6.79 during period of study in paddy ecosystem. The diversity indices were recorded as 1.82, 2.79, 4.17, 6.11, 6.79, 6.57, 4.43, 2.79 and 2.49 during 30$^{th}$, 32$^{nd}$, 34$^{th}$, 36$^{th}$, 38$^{th}$, 40$^{th}$, 42$^{nd}$, 44$^{th}$ and 46$^{th}$ standard weeks, respectively. Species richness was recorded highest during flowering and reproductive stages of crop *i.e.,* 36$^{th}$, 38$^{th}$ and 40$^{th}$ standard meteorological weeks and lowest at the time of transplanting *i.e.,* 30$^{th}$ standard week. Highest richness was recorded in the months of September and October, when pest incidence was high.

**Species evenness:** Species evenness was calculated by using Pielou's evenness index or Equitability (E). Pielou's evenness is an index that measures diversity along with species richness. A calculated value of Pielou's evenness ranges from 0 (no evenness) to 1 (complete evenness). Pielou's evenness index ranged from 0.35 to 0.91 during period of study in paddy ecosystem. The diversity indices recorded were 0.35, 0.51, 0.62, 0.85, 0.91, 0.91, 0.67, 0.53 and 0.51 during 30th, 32nd, 34th, 36th, 38th, 40th, 42nd, 44th and 46th standard weeks, respectively. Species evenness was higher during 38th and 40th standard week, while they were lowest at transplanting *i.e.,* during 30th standard week. This index indicated an uneven representation at the beginning and end of the crop growth period while more even representation was observed in the middle of the crop growth period at reproductive stage.

**Relative species abundance:** Dominance of species classified into three categories based on relative species abundance *viz.,* satellite (< 1%), sub-dominant (1-5%) and dominant species (> 5 %). In present study of paddy ecosystem a total of 22 spider species were recorded, of which six species were of dominant status *viz., P. pseudoannulata* (17.3%), *Chrysso sp.* (16.3%), *T. mandibulata* (15.4%), *T. elongata* (5.4%), *L. pseudoannulata* (5.1%) and *Leucage sp.* (5.1%); 15 species as sub-dominant *viz., R. grammica* (2.9%), *H. venatoria* (1.9%), *A. maculata* (1.9%), *A. inustus* (2.6%), *A. anasuja* (4.5%), *Z. notata* (2.6%), *Z. indica* (1.6%), *Chieranthium spp.* (2.2%), *Agelenopsis sp.* (1.6%), *A. formosana* (1.3%), *Hamataliwa sp.* (1.6%) *O. salticus* (3.5%), *B. aurocinctus* (4.2%), *E. falcata* (1.6%), *Mymarachne spp.* (1%) and one species as satellite *N. theisi* (0.6%). Among all species *P. pseudoannulata* was dominant and *N. theisi* was scarce (Table 1).

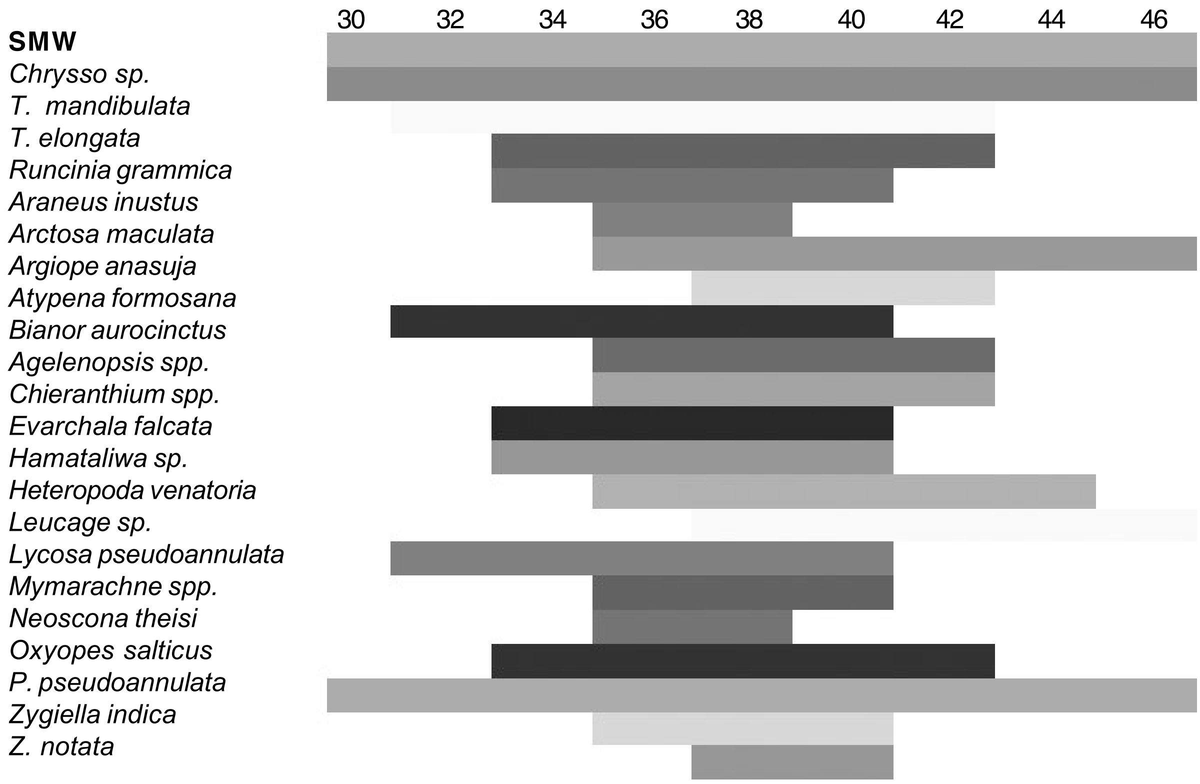


**Figure 3. Period of occurrence of spider species in rice ecosystem during *kharif* 2019**

The results of present investigations showed that the orb weavers were the dominant guild followed by ground runners, space web builders, stalkers, ambushers and sheet web builders, sac web builders and foliage runners. In paddy ecosystem during entire crop period 22 spider species were documented which belonged to 20 genera and 11 families *viz.,* Thomisidae, Sparassidae, Lycosidae, Araneidae, Tetragnathidae, Cheiracanthidae, Agelenidae, Linyphidae, Therididae, Oxyopidae and Salticidae. Majority of the population belonged to family Tetragnathidae followed by Lycosidae and Therididae. These three families constituted more than 60 per cent population in paddy crop. Out of 22 species, 6 species were designated as dominant, 15 species as sub-dominant and one species as satellite or rare. Tetragnathidae was recorded as dominant family, while Linyphiidae was least represented of the total population collected during crop period. The peak abundance of all species were recorded during flowering to reproductive stage *i.e.,* in the month of September to October. Whereas, *L. pseudoannulata, T. mandibulata* and *Chrysso spp.* were recorded throughout crop season from July to November and *N. theisi, Z. notata, Z. indica* and *Mymarachne* were recorded during reproductive stage only from September to October when pest incidence was high. The Shannon and Simpson indexes were lowest during transplanting and gradually increased up to reproductive stage and thereafter decreased at harvest. Pielou's evenness index indicated uneven representation at beginning and the end of the crop growth period and more even representation in the middle of the crop growth period at reproductive stage. Thus, rice ecosystem of Rajendranagar could be pronounced to be a stable ecosystem with moderate diversity of spiders. A diverse community indicated more complicated food chain, better flow of energy between the various trophic levels and enhanced stability. Moderate diversity of spiders in paddy ecosystem may be due to loss of natural habitat, intervention by cultural practices, low prey availability and high toxicity of chemical. Similar results were obtained by Sudhikumar (2005), who reported that 28 per cent of spiders belonged to stalkers category, 26 per cent to orb weavers, 13 per cent to ground runners, 11 per cent to space web builders, 10 per cent to ambushers, 7 per cent to foliage runners and 5 per cent to sheet web builders. The results were also accordance with Ashrith *et al.* (2017), who recorded Shannon index as 1.79, Simpson index 0.82, Evenness 0.88 and Margalef index 1.86 were highest during 70 DAS, 80 DAS, 110 DAS and 70 DAS, respectively, in direct rice crop. Yadav *et al.* (2016) reported that, Shannon- Wiener index (*H'*) which showed the species diversity was found to be ranging from 1.83 to 3.25 during the crop period, lowest at 15 DAT and highest at 90 DAT, respectively. Simpson index (ë) showed declining trend and indicated the dominance of some spider species *viz., T. maxillosa, T. mandibulata* and *O. javanus* during the advance stages of the paddy crop growth. The species richness (R) and evenness (E) were also recorded ranging from 1.94 to 3.78 and 0.52 to 0.64, respectively, which depended on the number of species in a community. Anita and Vijay (2016) recorded similar spider diversity of rice in Rajendranagar with high diversity between *kharif* and *rabi* seasons.

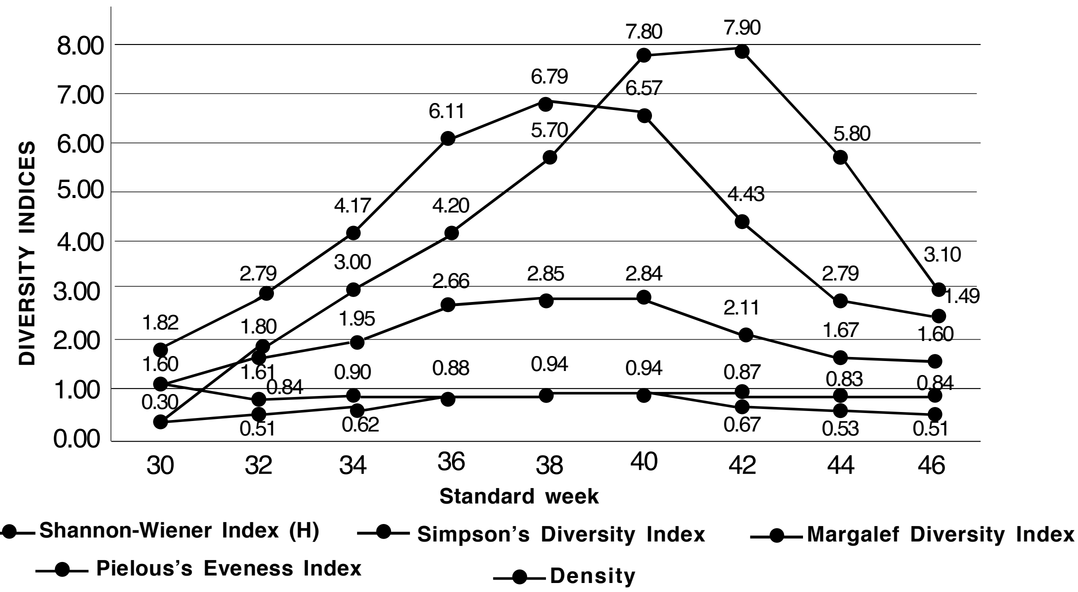


**Figure 4. Diversity, eveness and richness of spider fauna in rice ecosystem during *kharif* 2019**

## CONCLUSION

Overall twenty two spider species were documented in rice ecosystem belonging to 20 genera and 11 families with moderate diversity and high dominance throughout crop period. Moderate diversity might be due to deleterious side effects of intense use of pesticides, intervention by cultural practices and loss of natural habitat. Among the spider recorded *L. pseudoannulata, T. mandibulata* and *Chrysso sp.* were recorded throughout crop season from July to November, whereas *N. theisi, Z. notata, Z. indica* and *Mymarachne sp.* were recorded during reproductive stage from September to October. High diversity, eveness and richness were recorded during reproductive stage of among different stages of crop.

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Research Article
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# SOIL FERTILITY MAPPING OF PATANCHERU AREA, SANGA REDDY DISTRICT TELANGANA BY USING GPS-GIS

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## ABSTRACT

The present study was carried out to know the fertility status of Patancheru area of Sanga Reddy district, Telangana state by using GPS-GIS technology during the year 2020-2021. Total 132 soil samples from soil surface (0-20 cm) collected from the study area and analyzed for the soil physico-chemical properties (pH, EC, OC), available macronutrients (N, P, K, S, Ca, Mg) and available micronutrients (Fe, Mn, Cu, Zn). Their status was quantified and analytical data was interpreted and statistical parameters like range, mean, standard deviation and coefficient of variation were calculated. The pH of soils of study area varied from 6.14 to 9.20, most of the soils were found to be moderately to strongly alkaline (84.1 per cent) while EC varied from 0.09 to 4.33 dS $m^{-1}$, 99.32 per cent the soils were found to be high to very high in salinity. Organic carbon content varied from 0.11 to 1.25 per cent and categorized as low (5.0 per cent), medium (79.3 per cent) and high (15.7 per cent) content in soils. The soil available nitrogen, phosphorus and potassium ranged from 37.5 to 475.0, 15.4 to 59.8 and 176.2 to 1023.9 kg $ha^{-1}$, respectively. The soils were low (98.1 per cent) in available nitrogen. In respect of available phosphorus were medium (99.3 per cent). In case of available potassium were medium in 89.6 per cent of soils. The available sulphur varied from 0.5 to 32.1 mg $kg^{-1}$. The soils were medium (76.6 per cent) in available sulphur content. The exchangeable calcium and magnesium were sufficient in all samples. Available Zn, Cu, Fe and Mn were deficient in 90.7, 45.6, 98.4 and 88.8 per cent of soils respectively.

**Keywords:** GPS-GIS, physio-chmical properties, mapping, macro and micro nutrients, soil fertility

The modern geospatial technologies like Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) plays a crucial role in preparing soil fertility maps and can play a vital role in soil management. GPS and GIS helps in analyzing and storing spatial data that helps us to make better decisions in particular land development for agriculture environmental protection and restoration. In precision agriculture, farmer's use GPS and GIS as yield monitors and variable technology to apply appropriate quantities of input in different parts of field (Adornado and Yoshida 2008). Land use planners and developers use GPS and GIS to assess soil protection of surface and wetlands. Composite soil sampling was done by GPS instrument helps in knowing the latitude and longitude of that particular location of collected soil sample. It also got great significance in agriculture for future monitoring of soil nutrient status of different locations.

Studies on soil fertility status of Patancheru area in Sanga Reddy district, Telangana was scarce. As such information is not available for Patancheru area in Sanga Reddy district, Telangana and is essential in planning soil fertility management on an area basis. The proposed study was planned with the objective of identifying available nutrients constraints in soils of Patancheru area of Sanga Reddy district located in Central Telangana Zone of Telangana state.

## MATERIAL AND METHODS

### Study Area

The study was carried out at Patancheru area in Sanga Reddy district and comes under Central Telangana Zone. The site is located at $17^0$30' 55.68"N, $78^0$14'50.26'' E in Sanga Reddy district. The region experiences hot and dry summer throughout the year except during the south west monsoon season. The hot (summer) season is from March to May. From March onwards the temperature continues to rise and May is generally the hottest month in the year. The period from June to September constitutes the south-west monsoon (SW rainy) season and October to December is north-east monsoon (NE rainy) season. The cold (winter) season is from January to February.

### Sample Collection and Analysis

GPS based soil samples (132 No.) of 0-20 cm depth were collected from Patancheru area of Sanga Reddy district. Soil samples collected from each of the sites were dried under shade. The air dried samples was then pounded with wooden pestle and mortar

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and passed through a 2 mm sieve and then stored for determination of various soil properties. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973). Organic carbon (OC) was determined using the procedure given by Walkley-Black (1934). Available nitrogen (N) was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen *et al.*, 1954). Available potassium (K) was determined using the ammonium acetate method (Jackson, 1973). Available sulphur (S) was measured using 0.15 percent calcium chloride ($CaCl_2.2H_2O$) as an extractant (Chopra and Kanwar, 1991). Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA using the procedure outlined by Lindsay and Norvell (1978). Variability of data was assessed using mean standard deviation and coefficient of variation for each set of data. Availability of N, P, K and S in soils was interpreted as low, medium and high and that of Ca, Mg, Zn, Fe, Cu and Mn interpreted as deficient and sufficient by following the criteria given in Table 1.

The results obtained from the physico-chemical and chemical analysis of the soil samples collected at 132 soil sampling points in Patancheru area using GPS in the study area were used for the generation of soil fertility maps employing the kriging coefficient and interpolation techniques in Arcgis software, wherein each soil quality parameter was designated in to several classes. Kriging is a geo-statistical interpolation method which deals with the distance and degree of variation between known data points when estimating values in unknown areas. A kriged estimate was a weighed linear combination of known sample values around the point to be estimated.

pH rating were < 6.5 - slightly acidic, 6.5 – 7.3 - neutral, 7.3 – 7.8 - slightly alkaline and > 7.8 - moderately to strongly alkaline. EC rating were < 0.25-Low saline, 0.25-0.75-Medium saline, 0.75-2.25-high saline and > 2.25-very high saline.

## RESULTS AND DISCUSSION

### Soil Reaction

Soils of the Patancheru area were slightly acidic to strongly alkaline (6.14 to 9.20) in reaction with a mean pH of 8.08, standard deviation of 0.53 and coefficient of variation of 6.58 percent (Table 2). The CV of soil pH indicates that spatially it did not vary much. The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases because of continous cultivation of paddy crop.

**Table 1. Rating for soil organic carbon and available nutrients**

| S.No | Nutrient / parameter | Rating | | | Reference |
|---|---|---|---|---|---|
| | | Low | Medium | High | |
| 1 | Organic Carbon (per cent) | <0.5 | 0.5-0.75 | >0.75 | Ramamoorthy and Bajaj (1969) |
| 2 | Available Nitrogen (kg ha$^{-1}$) | <280 | 280-560 | >560 | |
| 3 | Available $P_2O_5$ (kg ha$^{-1}$) | <22.9 | 22.9-56.3 | >56.3 | Muhr *et al.* (1965) |
| 4 | Available $K_2O$ (kg ha$^{-1}$) | <129.6 | 129.6-336 | >336.0 | |
| 5 | Available Sulphur (mg kg$^{-1}$) | <10 | 10-20 | >20 | Hariram and Dwivedi (1994) |
| | | Deficient | | Sufficient | |
| 6 | Exchangeable Calcium (cmol (p$^+$) kg$^{-1}$ soil) | <1.5 | | >1.5 | Tandon(1991) |
| 7 | Exchangeable Magnesium (cmol (p$^+$) kg$^{-1}$ soil) | <1.0 | | >1.0 | Tandon (1991) |
| 8 | Available Zinc (ppm) | <0.6 | | >0.6 | Lindsay and Norvell (1978) |
| 9 | Available Copper (ppm) | <0.2 | | >0.2 | |
| 10 | Available Iron (ppm) | <4.5 | | >4.5 | |
| 11 | Available Manganese (ppm) | <1.0 | | >1.0 | |

The results are in agreement with those reported by Patil *et al.* (2016). The spatial variability of pH depicted in Figure 1. The pH of 0.05 per cent (7 ha) was slightly acidic, 2.30 per cent (351 ha) was neutral, 12.74 per cent (1942 ha) was slightly alkaline and 84.91 per cent (12938 ha) was moderately alkaline to strongly alkaline in soil reaction.

**Electrical Conductivity**

The EC of soils in the study area was in the range of 0.09 to 4.33 dS $m^{-1}$ with mean value of 2.16 dS $m^{-1}$ and standard deviation of 1.14. The CV (52.81) of EC values indicate that salt content in the study area varied spatially (Table 2). Higher level of soluble salts in the study area was due to arid climatic condition and continuous cultivation of paddy. Patil *et al.* (2017) and Patil *et al.* (2018) also reported that, soils of Bedwatti sub watershed of Koppal district varied spatially with respect to solubility of salt. The spatial variability of EC pertaining to Pathancheru area depicted in Figure 2. The EC of 0.05 per cent (8 ha) was low saline, 0.63 per cent (96 ha) was moderately saline, 64.04 per cent (9758 ha) was high saline and 35.28 per cent (5375 ha) was very high saline.

**Table 2. Physico-chemical properties in Patancheru area of Sanga Reddy district**

| Statistics | pH | EC (dS $m^{-1}$) | OC (per cent) |
|---|---|---|---|
| Mean | 8.08 | 2.16 | 0.63 |
| Range | 6.14-9.20 | 0.09 - 4.33 | 0.11-1.25 |
| SD | 0.53 | 1.14 | 0.24 |
| CV (%) | 6.58 | 52.81 | 38.14 |

**Soil Organic Carbon**

Soil organic carbon content (OC) of study area varied from 0.11 to 1.25 per cent with a mean and standard deviation value of 0.63 percent and 0.24, respectively. The CV of 38.14 percent for organic carbon content indicated that, in the study area organic carbon varied spatially (Table 2). Satish *et al.* (2018) also reported that OC varied spatially in Brahmanakotkur watershed of Andhra Pradesh. Swapnil *et al.* (2012) reported in soils of Savli micro-watershed of Wardha district, Maharashtra that organic carbon content ranged between 0.41 to 1.86 per cent. Soils of study area was varied greatly in soil organic carbon the spatial variability map generated by GIS revealed that 5.0 per cent (756 ha) of the study area was low in organic carbon, 79.3 per cent (12088 ha) was medium and 15.7 per cent (2392 ha) was high in organic content in soils (Figure 3).

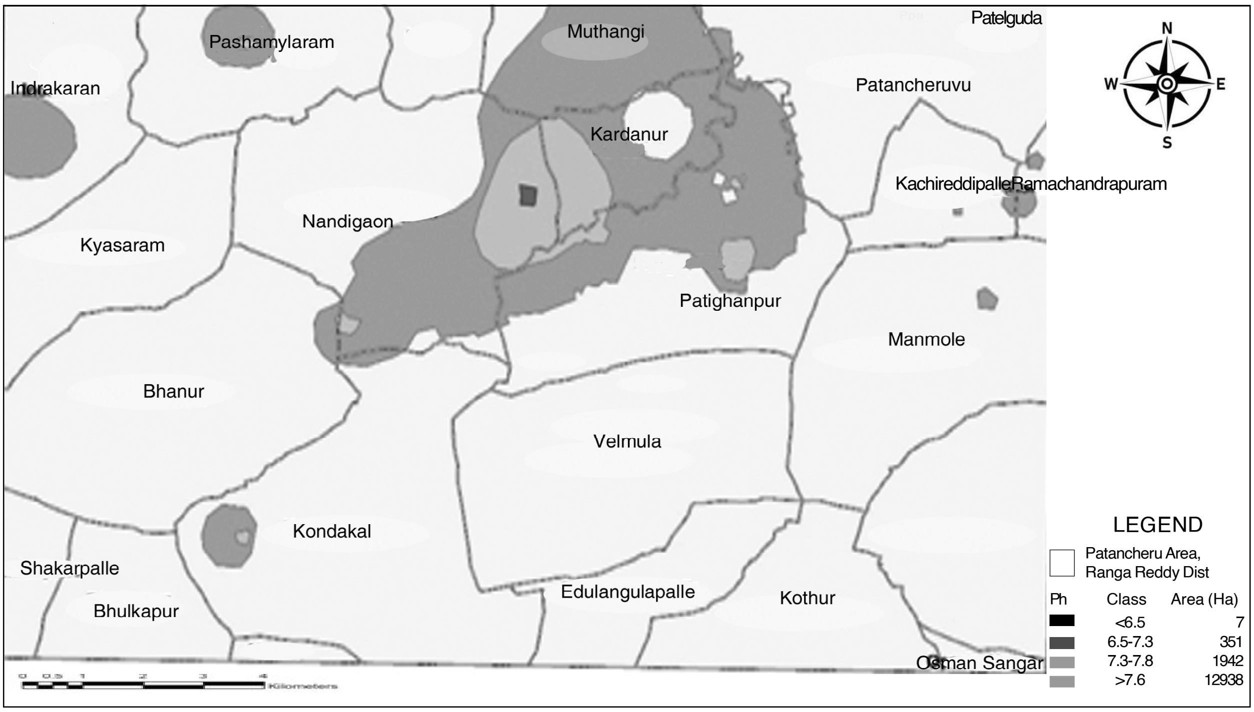


**Figure 1: Status of pH in the soils of Patancheru area, Sanga Reddy district, Telangana State**

**Available Macronutrients**

**Available Nitrogen**

The available N in soils of the study area ranged from 37.5 to 475.0 kg $ha^{-1}$ with a mean of 225.9 kg $ha^{-1}$ and SD of 84.7. The CV value of 37.5 percent indicates that available N in soils varied spatially.

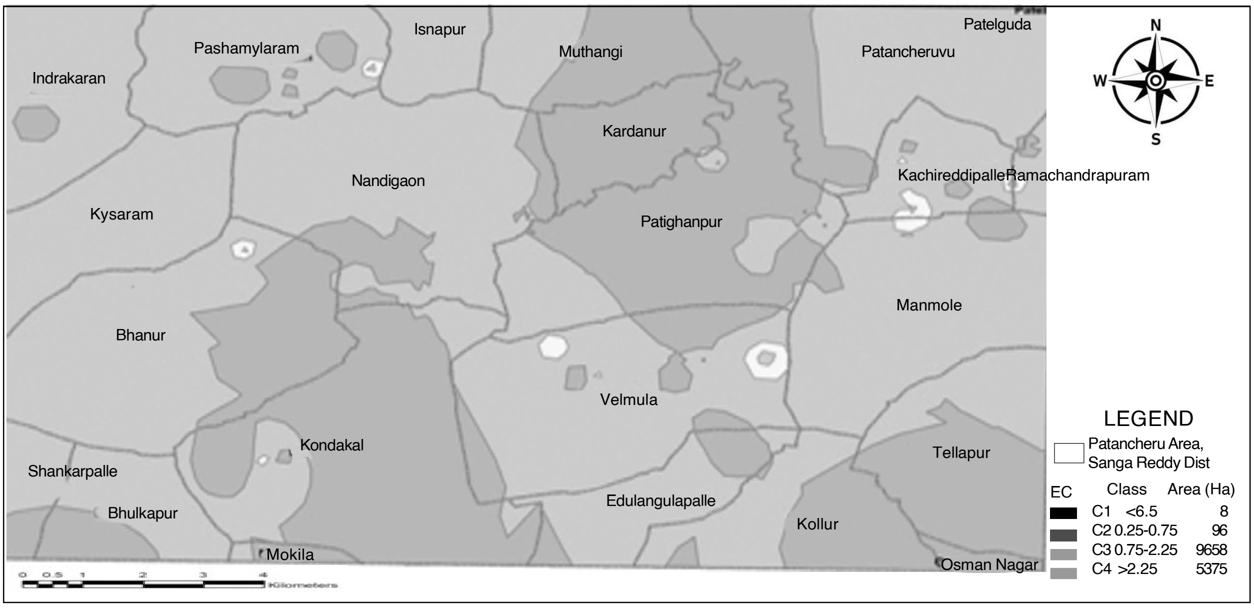


**Figure 2: Status of EC in the soils of Patancheru area, Sanga Reddy district, Telangana state**

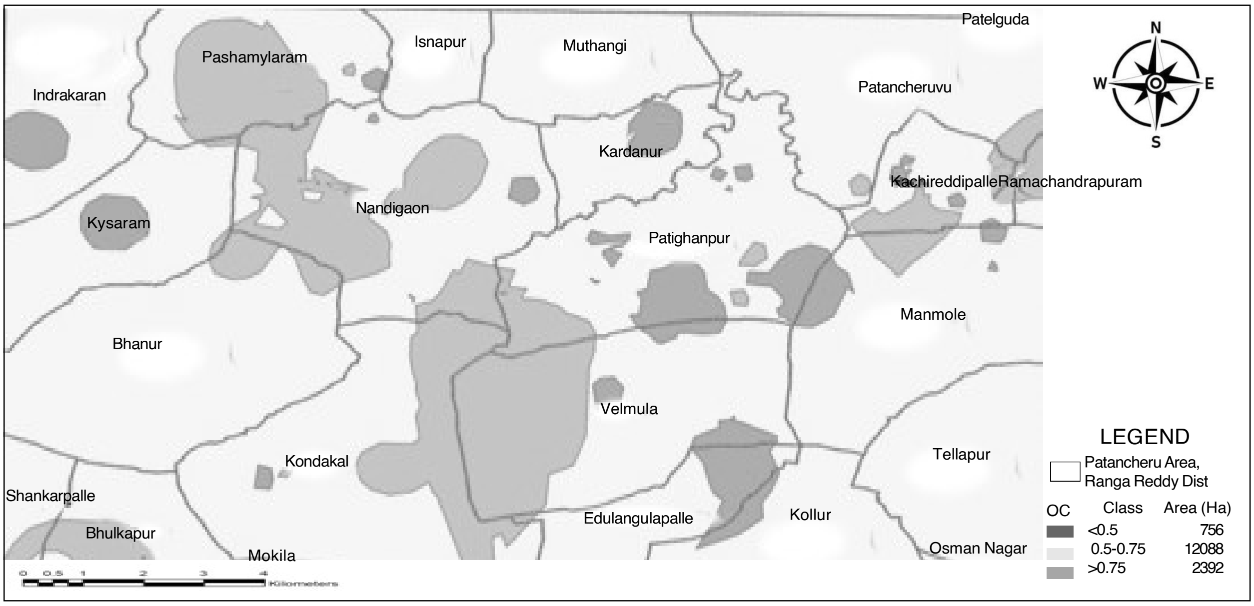


**Figure 3: Status of OC in the soils of Patancheru area, Sanga Reddy district, Telangana state**

GIS mapping revealed that, the nitrogen content of 98.1 per cent (14946 ha) was low and 1.9 per cent (292 ha) was medium in available nitrogen (Table 3 and Figure 4). The low N content could be attributed to soil management, varied application of FYM and fertilizer to previous crops. Nitrogen is the most limiting nutrient in soils as its availability decreases due to fixation and volatilization losses. Another possible reason may also be due to low organic matter and high temperature which facilitate faster degradation and removal of organic matter leading to nitrogen deficiency. deficiency. Similar results was reported by Pulakeshi *et al.* (2012) and Patil *et al.* (2017).

## Available Phosphorus

The available phosphorus content in soils of Patancheru area ranged from 15.4 to 59.8 kg ha$^{-1}$ with an average and SD values of 31.43 and 8.92, respectively. The CV of 28.39 per cent for available phosphorus distribution in the study area indicated that, it varied spatially (Table 3). The spactial distribution of available phosphorus pertaining to Pathancheru area depicted in Figure 5 revealed that it was medium in area of 15124 ha (99.3 per cent) whereas low in 114 ha (0.7 per cent). Semi-arid environment with low rainfall and continuous use of high analysis fertilizers especially DAP without knowing the crop nutrient requirement and

**Table 3. Available primary nutrients status in Patancheru area of Sanga Reddy district**

| Statistics | Available N (kg ha$^{-1}$) | Available P (kg ha$^{-1}$) | Available K (kg ha$^{-1}$) |
|---|---|---|---|
| **Mean** | 225.98 | 31.43 | 531.81 |
| **Range** | 37.5-475.0 | 15.4-59.8 | 176.2-1023.9 |
| **SD** | 84.74 | 8.92 | 223.24 |
| **CV (%)** | 37.50 | 28.39 | 41.98 |

soil phosphorus build up and contributing towards medium to high available phosphorus status in these soils. Satish *et al.* (2018) and Sashikala *et al.* (2019) also found similar observations.

**Available Potassium**

The available potassium in soil samples of study area ranged from 176.2 to 1023.9 kg ha$^{-1}$ with mean and SD values of 531.8 and 223.24, respectively. The CV of 41.98 for available potassium indicates that, it varied spatially in the study area (Table 3). Mapping of available potassium by using GIS (Figure 6) revealed that total area under medium range was 13653 ha (89.6 per cent) and high range were 1584 ha (10.4 per cent). Soils were able to maintain a sufficient or even high level of exchangeable K and provide a good supply of K to plants for many years. The medium to higher content of available K in soils of study area may be due to the predominance of K-rich micaceous and feldspar minerals in parent material. Similar results were observed by Srikant *et al.* (2008) and Sashikala *et al.* (2019).

**Available Sulphur**

The available sulphur content of the soils of the study area ranged from low to high, but most of the samples were medium in available sulphur (Figure 7). The available sulphur content in study area ranged between 0.5 to 32.1 mg kg$^{-1}$with a mean, SD, CV of 12.78 mg kg$^{-1}$, 6.03, 47.13 respectively (Table 4). The spactial distribution of available sulphur pertaining to Patancheru area depicted in Figure 7 revealed that it was high in area of 672 ha (4.4 per cent) and medium in area of 11658 ha (76.6 per cent) whereas low in 2899 ha (19.0 per cent). Kumar *et al.* (2019) also reported the similar findings with the available sulphur in the soils ranged from 5.12 to 35.93 mg kg$^{-1}$ (low to high) with the mean value 16.14 mg kg$^{-1}$. The total sulphur in soil was present in organic combination, therefore soils which are rich in organic matter will have high level of sulphur and also coarse texture soils have low amount of sulphur than fine textured soils due to leaching losses and adsorption of sulphates on organic matter leads to unavailable to plants. The results indicated that sufficiency of available

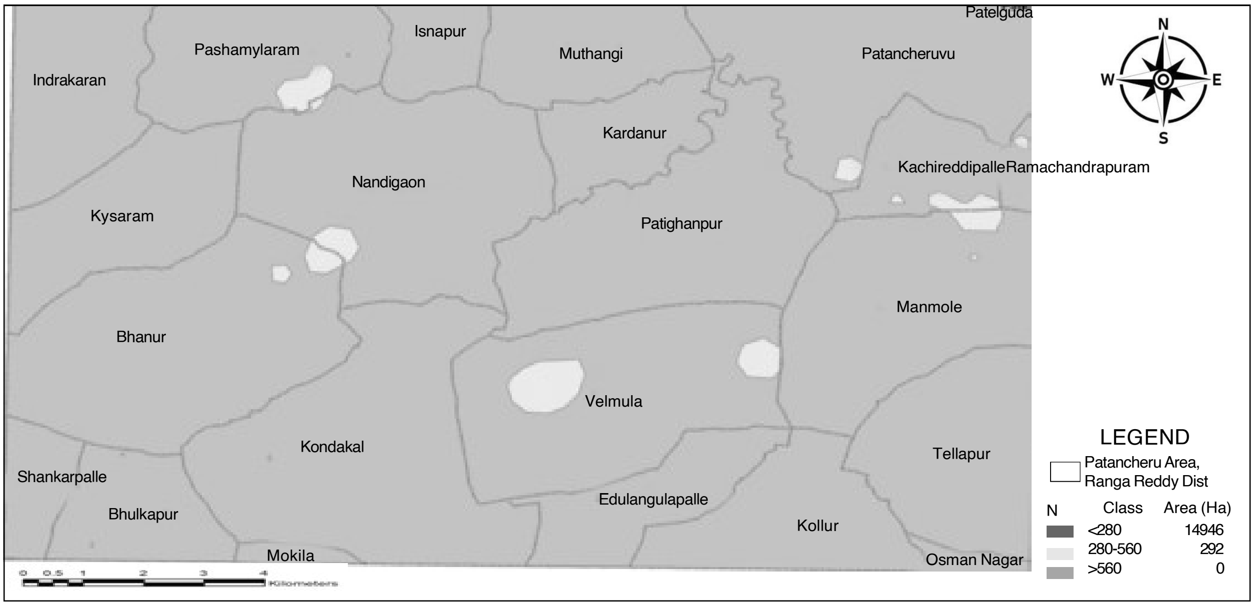


**Figure 4: Status of Available N in the soils of Patancheru area, Sanga Reddy district, Telangana state**


**Figure 5: Status of Available $P_2O_5$ in the soils of Patancheru area, Sanga Reddy district, Telangana state**

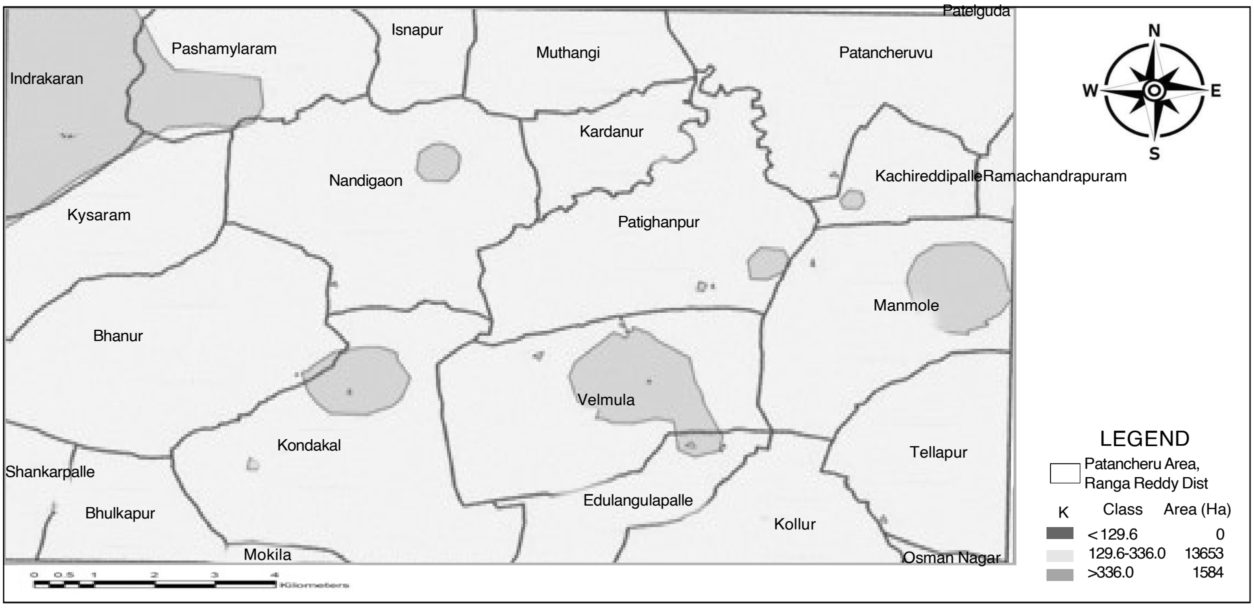


**Figure 6: Status of Available $K_2O$ in the soils of Patancheru area, Sanga Reddy district, Telangana state**

sulphur was directly proportional to organic sulphur content of soil.

### Available Calcium and Magnesium

The available calcium content in study area ranged between 1.5 to 15.1 c mol ($p^+$) $kg^{-1}$ with a mean, SD, CV of 11.54 c mol ($p^+$) $kg^{-1}$, 1.6, 14.3 respectively (Table 4). The spatial distribution of available calcium pertaining to Patancheru area depicted in Figure 8 revealed that it was sufficient in all samples. The available magnesium content in study area ranged between 4.1 to 11.2 c mol ($p^+$) $kg^{-1}$ with a mean, SD, CV of 6.3 c mol ($p^+$) $kg^{-1}$, 1.35 and 21.48 respectively (Table 4). The spatial distribution of available magnesium pertaining to Patancheru area depicted in Figure 9 revealed that it was sufficient in all samples. Similar findings were reported by Parhad *et al.* (2018) in eastern part of Port Said near Malaha, Dhule district in Maharashtra.

**Table 4. Available secondary nutrients status in Patancheru area of Sanga Reddy district**

| Statistics | Available S (kg $ha^{-1}$) | Available $Ca^{+2}$ (kg $ha^{-1}$) | Available K (kg $ha^{-1}$) |
|---|---|---|---|
| Mean | 225.98 | 31.43 | 531.81 |
| Range | 37.5-475.0 | 15.4-59.8 | 176.2-1023.9 |
| SD | 84.74 | 8.92 | 223.24 |
| CV (%) | 37.50 | 28.39 | 41.98 |

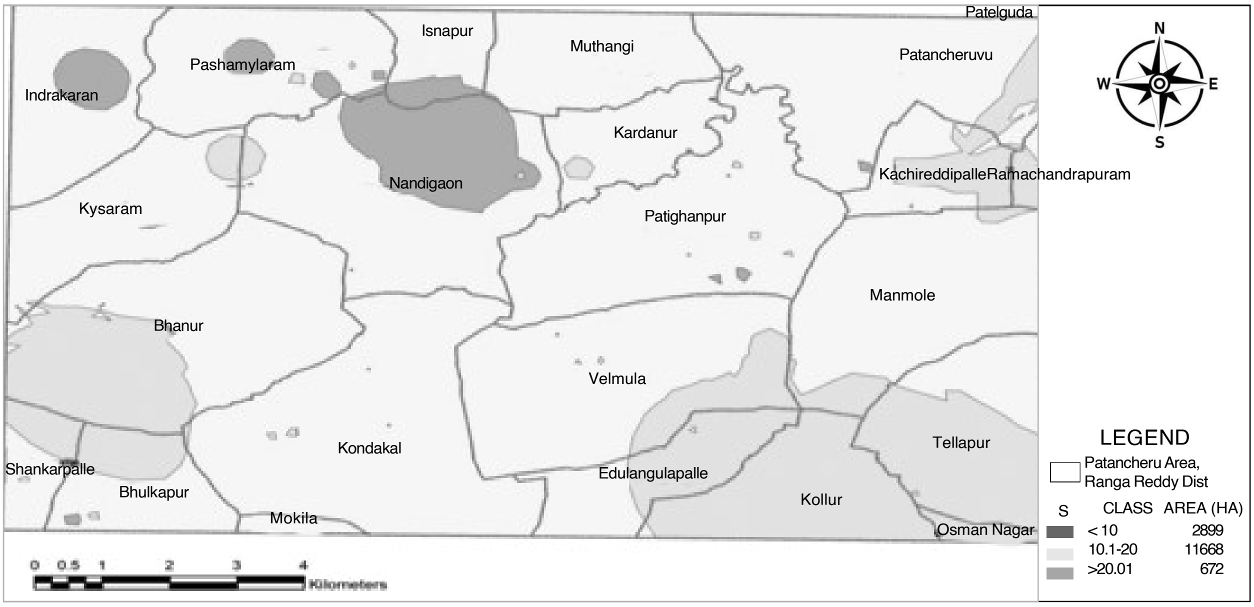


**Figure 7: Status of Available S in the soils of Patancheru area, Sanga Reddy district, Telangana state**

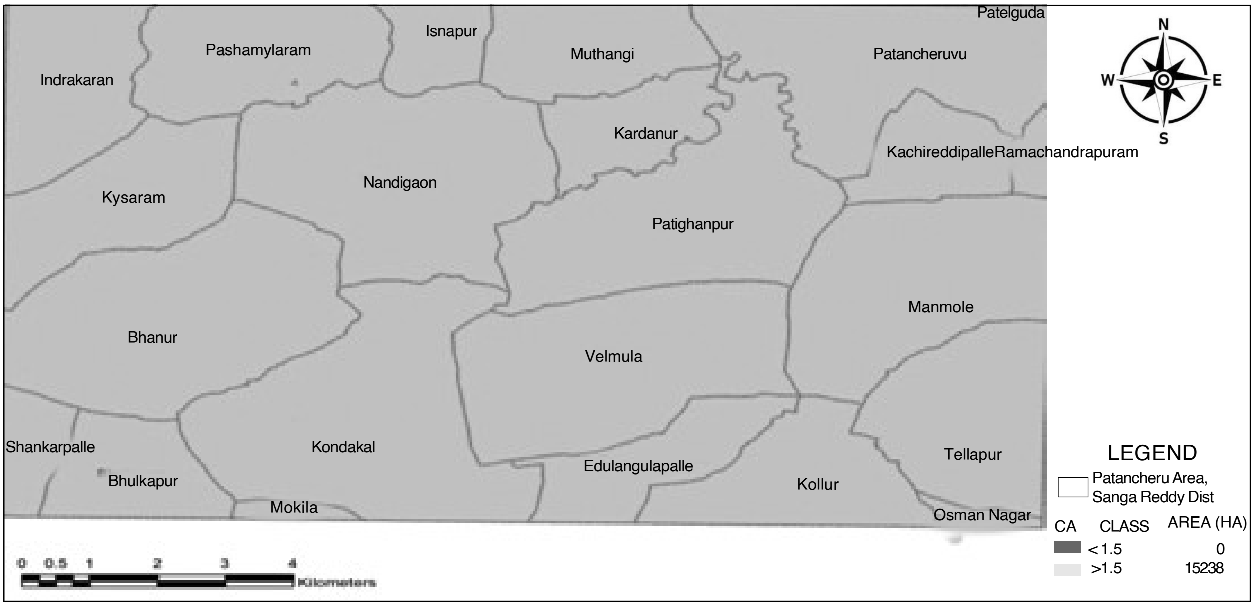


**Figure 8: Status of Available Ca in the soils of Patancheru area, Sanga Reddy district, Telangana state**

## Available Micronutrients

### Available Zinc

The available zinc in surface soil samples of study area varied from 0.09 to 1.03 mg kg$^{-1}$ with a mean and SD values of 0.51 and 0.18, respectively. The CV of 36.39 per cent for available zinc indicates that it was varied spatially in the study area (Table 5). The spatial distribution map (Figure 10) of available zinc revealed that zinc content in an area of 90.70 per cent (13822 ha) was deficient and 9.30 per cent (1418 ha) was sufficient in soil samples. Similar resultswere observed by Patil *et al.* (2016) and Satish *et al.* (2018) in soils of Dindur sub-watershed of Karnataka and Brahmanakotkur watershed of Andhra Pradesh, respectively.

### Available Copper

The available copper content of study area soil samples ranged from 0.02 to 0.92 ppm with the mean of 0.19, SD of 0.15 and CV of 77.7 (Table 5). The spatial variability of available copper pertaining to Patancheru area revealed that study area has 45.64 per cent (6956 ha) was sufficient and 54.36 per cent (8286 ha) was deficient in soil samples (Figure 11). Raghupathi (1989) reported that the available copper


**Figure 9: Status of Available Mg in the soils of Patancheru area, Sanga Reddy district,Telangana state**

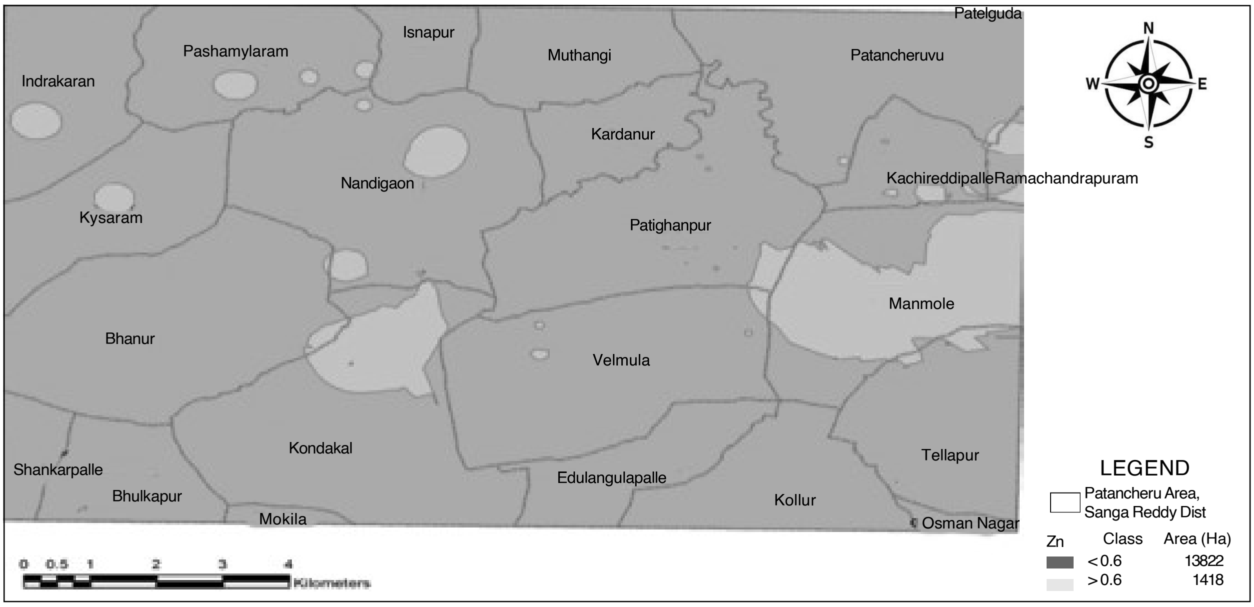


**Figure 10: Status of Available Zn in the soils of Patancheru area, Sanga Reddy district, Telangana state**

**Table 5. Available minor nutrients status in Patancheru area of Sanga Reddy district**

| Statistics | Zn (ppm) | Cu (ppm) | Fe (ppm) | Mn (ppm) |
|---|---|---|---|---|
| Mean | 0.51 | 0.19 | 3.29 | 0.82 |
| Range | 0.09-1.03 | 0.02-0.92 | 0.56-7.02 | 0.09-2.30 |
| SD | 0.18 | 0.15 | 1.47 | 0.44 |
| CV (%) | 36.39 | 77.75 | 44.58 | 53.32 |

content ranged from 0.4 to 1.2 ppm in soils of Karnataka. Similar results have also been observed by Patil *et al.* (2016).

**Available Iron**

The available iron in the study area varied from 0.56 to 7.02 mg $kg^{-1}$ with a mean and SD value


**Figure 11: Status of Available Cu in the soils of Patancheru area, Sanga Reddy district,Telangana state**

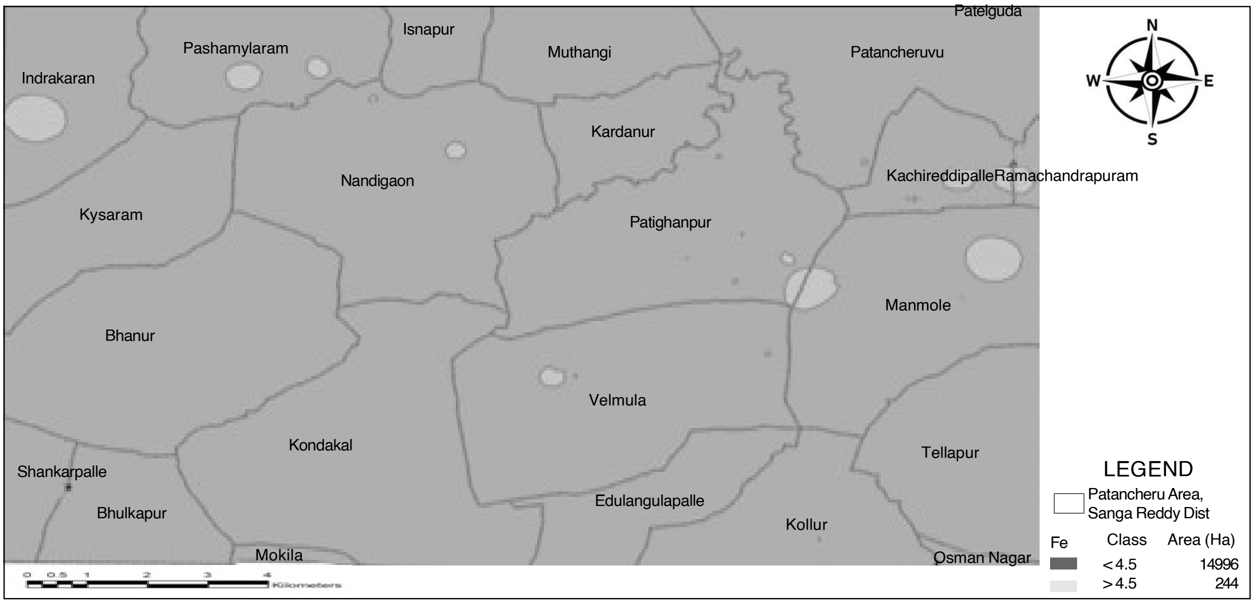


**Figure 12: Status of Available Fe in the soils of Patancheru area, Sanga Reddy district, Telangana state**

of 3.29 and 1.5, respectively. The CV of 44.58 percent for available iron indicates that, it varied spatially in the study area (Table 5). Hence, the iron content in area of 98.4 per cent (14996 ha) was deficient and 1.60 cent (244 ha) was sufficient in soils (Figure 12). The available iron in surface soils has no regular pattern of distribution as also reported by Nayak *et al.* (2002) and Satish *et al.* (2018). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

### Available Manganese

The available manganese content of the study area region ranged from 0.09 to 2.30 ppm with a mean of 0.82 ppm, SD of 0.44 and CV of 53.3 (Table 5) . The Mn content in area of 88.88 per cent (13545 ha) was deficient and 11.12 per cent (1695 ha) was sufficient in soils (Figure 13). Similar findings were reported by Ramesh and Rao (2005) and Nandy *et al.* (2012).

## CONCLUSION

From the study, it can be concluded that, most of the soils in Patancheru area of Sanga Reddy was moderately to strongly alkaline in soil reaction with high to very high salinity. Soil organic carbon content was low to high. Available nitrogen was low, available phosphorus was medium, available potassium was

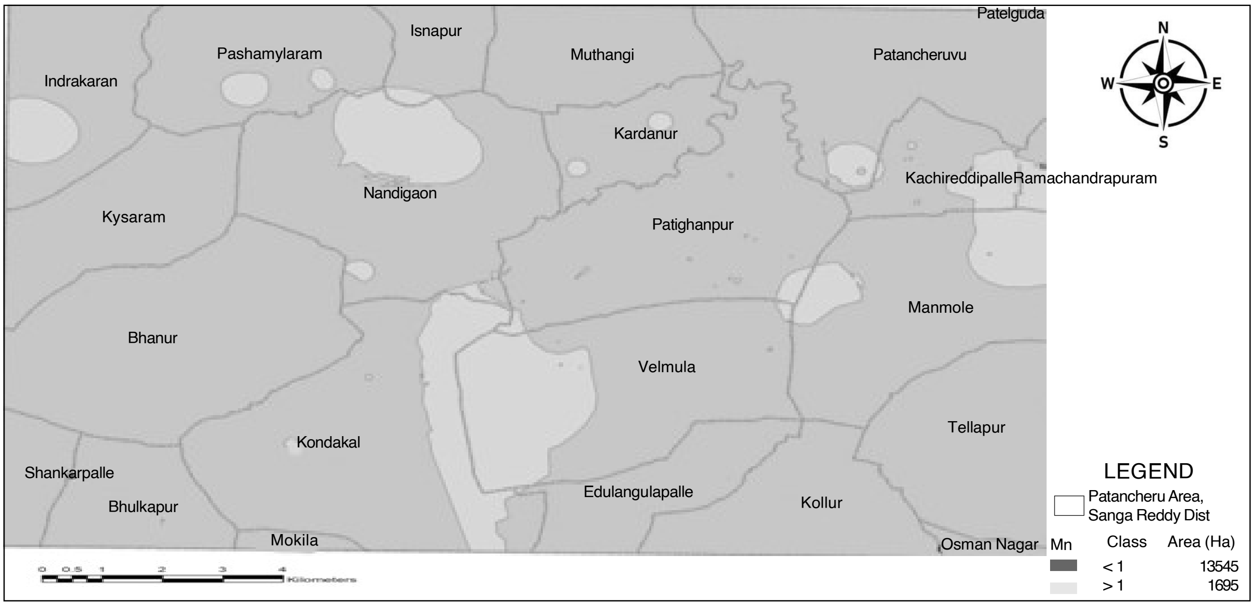


**Figure 13: Status of Available Mn in the soils of Patancheru area, Sanga Reddy district,Telangana state**

medium to high and sulphur was medium in bulk of the soil samples. Exchangeable calcium and magnesium was sufficient in all the soil samples. Available Zn, Cu, Fe and Mn were deficient in 90.7, 45.6, 98.4 and 88.8 per cent of soil samples respectively. The mapping of nutrients by GIS technique in the study area revealed that available N, Zn, Cu, Mn and Fe were the important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient nutrients may be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

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Research Article
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# DECIPHERING INHERITANCE PATTERN OF RESISTANCE TO FUSARIUM WILT DISEASE IN CASTOR (*Ricinus communis* L.)

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## ABSTRACT

Castor is an important non-edible oilseed crop having varied industrial applications. Fusarium wilt caused by *Fusarium oxysporum* f. sp. *ricini* is a serious disease in castor. Chemical management of fusarium wilt is troublesome due to soil borne nature of the pathogen. Utilization of genetic resistance is the best possible solution for management of fusarium wilt. The present study was aimed at genetic characterization of three resistant germplasm lines namely AP-70, AP-127 and AP-163. The resistant lines were crossed with a susceptible inbred, 'JI-35' to generate $F_1$s and $F_2$ populations. The parents, $F_1$s and $F_2$ individuals were screened for fusarium wilt resistance in the wilt sick plot maintained at ICAR-Indian Institute of Oilseeds Research, Hyderabad, India. The reaction of $F_1$s indicated that the nature of fusarium wilt resistance in AP-70 and AP-163 is recessive while it is dominant in AP-127. The segregation of resistance and susceptibility in $F_2$ populations showed that fusarium wilt resistance in AP-70 and AP-163 is conferred by two recessive genes involving complementary interaction while two dominant complementary genes governs fusarium wilt resistance in AP-127. The resistant lines used in the present study are largely underutilized in castor improvement leaving scope for its exploitation in widening the genetic base of breeding lines in castor improvement.

**Keywords:** Fusarium wilt, genetic characterization, castor

Castor (*Ricinus communis* L.) is an industrially important oilseed crop. It belongs to the monotypic genus *Ricinus* under Euphorbiaceae family. Castor seed oil and its derivatives are important raw materials for manufacturing industries such as lubricants, cosmetics, varnishes and paints (Ogunniyi, 2006; Mutlu and Meier, 2010). Castor growing areas in the world are distributed in several countries out of which India, China, Mozambique and Brazil are the major producers. India contributes 85 per cent of the world's production, which is approximately 1.2 million tonnes (FAOSTAT, 2019). Castor production is hampered by several biotic and abiotic stresses out of which fusarium wilt caused by *Fusarium oxysporum* f. sp. *ricini* is a major disease, which can cause up to 77 per cent yield loss depending upon the stage at which the plant wilts (Pushpavathi *et al.* ,1998). *Fusarium oxysporum* f. sp. *ricini* is primarily a soil borne pathogen however seed borne nature also reported (Naik, 1994). Owing to the soil borne nature of fusarium wilt, its management by chemical means is difficult. Thus, imparting genetic resistance in castor inbred lines is inevitable for management of fusarium wilt. To utilize newly identified resistant castor germplasm, genetic characterization of these sources for fusarium wilt resistance is a prerequisite. Information regarding genetics of the trait is needed to decide the suitable breeding approach. Recently, Shaw (2018) screened 300 castor lines including indigenous and exotic accessions for fusarium wilt resistance. This screening led to the identification of several fusarium wilt resistant lines, which are not much exploited in castor breeding programs yet leaving scope for widening the genetic base of castor inbred lines and hybrids. In this context, the present study was aimed at genetic characterization of three fusarium wilt resistant castor germplasm lines.

## MATERIAL AND METHODS

### Parental material for crossing work

In the present study, three resistant (AP-70, AP-127 and AP-163) and one susceptible (JI-35) inbred lines were used. The inbred lines AP-70, AP-127 and AP-163 were derived through single seed descent method from the germplasm accessions RG-1707, RG-2944 and RG-27, respectively maintained at the genebank of ICAR-IIOR (Shaw, 2018; Senthilvel

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*et al*., 2017). These lines consistently showed resistance reaction in field as well as glass house screenings (Shaw, 2018). The inbred line JI-35 is the susceptible check in screening for fusarium wilt resistance under All India Co-ordinated Research Project (AICRP) on castor.

**Development of segregating populations**

Each of the resistant line was crossed with the susceptible line JI-35. Thus, three crosses AP-70 × JI-35, AP-127 × JI-35 and AP-163 × JI-35, were made during post rainy season (October-February) of 2015-16. Adequate precautions were followed to prevent contamination by natural outcrossing during crossing program. Parents used as female in crossing were emasculated before anthesis and covered with butter paper bag. The emasculated inflorescences were pollinated with pollen from covered inflorescences of JI-35. The $F_1$ plants were raised in the field and true $F_1$s were identified based on morphological characters like stem colour, presence of wax on plant parts, spine on capsule etc. The true $F_1$ plants were selfed by covering the inflorescence with butter paper bag before opening of flowers. The selfed seeds ($F_2$) from $F_1$s of all the three crosses were harvested.

**Screening of $F_1$ and $F_2$ generations for resistance to fusarium wilt**

The $F_1$s and $F_2$ populations along with parents were screened for fusarium wilt resistance in the permanent wilt sick plot maintained at the experimental farm of ICAR-IIOR, Rajendranagar, Hyderabad (India). This permanent wilt sick plot is in use since few decades to screen castor material for fusarium wilt resistance. It is maintained by repeated incorporation of wilt affected plant debris and continuous growing of susceptible cultivars. The *Fusarium oxysporum* f. sp. *ricini* inoculum, mass multiplied on sorghum grains, is added in the field to maintain high inoculum level. The parents, $F_1$s and $F_2$ seeds were sown in 4.5 m long rows with the spacing of 60 cm (between rows) × 45 cm (between plants) during the rainy season (June-September) of 2018. The standard susceptible (JI-35) and resistant (48-1) checks were sown after every five rows to test uniform availability of inoculum across the field. The plants were observed continuously for disease reaction up to 150 days after sowing (DAS). The plants surviving up to 150 DAS without any disease symptoms were scored as resistant and plants showing disease symptoms at any point of time during the period of experiment were scored as susceptible.

**Data analysis**

Chi-square test was used to check goodness of fit of wilt resistance scores of $F_2$ populations to various classical Mendelian ratios.

## RESULTS AND DISCUSSION

All the $F_1$ plants of crosses AP-70 × JI-35 and AP-163 × JI-35 succumbed to fusarium wilt indicating that the nature of resistance in AP-70 and AP-163 could be recessive. The recessive nature of wilt resistance in castor has been reported in previous studies (Lavanya *et al.,* 2011; Shaw *et al.,* 2018). The $F_1$ plants of the cross AP-127 × JI-35 survived till the end of the experiment indicating dominant nature of resistance in AP-127. Several other authors also reported dominant nature of wilt resistance in castor (Rao *et al.,* 2005; Shankar *et al.,* 2010; Singh *et al.,* 2011; Shaw *et al.,* 2018).

The segregation pattern of $F_2$ population for fusarium wilt resistance in all three crosses is given in Table 1. The calculated $\chi^2$ values for all the crosses were lesser than the table value (3.84, $p$=0.05 at 1 df) indicating non-significant deviation between the observed and expected Mendelian ratios. The $F_2$ plants of the crosses namely AP-70 × JI-35 and AP-163 × JI-35 segregated in the ratio of 7 (resistant) : 9 (susceptible) indicating the role of two

**Table 1. Reaction of $F_2$s to fusarium wilt in wilt sick plot**

| Cross | Total Plants | Observed | | Expected | | Ratio (R:S) | Chi-square value |
|---|---|---|---|---|---|---|---|
| | | Resistant | Susceptible | Resistant | Susceptible | | |
| AP-163 × JI-35 | 96 | 46 | 50 | 42.0 | 54.0 | (7:9) | 0.680 |
| AP-70 × JI-35 | 99 | 48 | 51 | 43.3 | 55.7 | (7:9) | 0.910 |
| AP-127 × JI-35 | 75 | 42 | 33 | 42.2 | 32.8 | (9:7) | 0.002 |

$\chi^2$ (table) for 1 df=3.841 at $p$=0.05.

recessive genes involving complementary epistasis conferring resistance for fusarium wilt in AP-70 and AP-163. Susceptibility in $F_1$s of these resistant sources corroborates results of $F_2$ ratio observed for resistant and susceptible phenotypes. The segregation of (AP-70 × JI-35) $F_2$s for fusarium wilt is shown in Fig. 1. Similar report of wilt resistance governed by two recessive genes involving complementary epistasis has been reported previously in castor (Shaw *et al.* 2018) and pigeonpea (Ajay *et al.,* 2013). The probable allelic combinations of parents, $F_1$ and $F_2$ genotypes of castor crosses studied for fusarium wilt is presented in Table 2. Considering two loci responsible for wilt resistance, they were designated as $R_1$ and $R_2$. In case of AP-70 and AP-163, it is hypothesized that resistance to fusarium wilt is expressed when one of the genes or both the genes are in homozygous recessive condition ($R_1R_1r_2r_2$/ $r_1r_1R_2R_2$/ $r_1r_1r_2r_2$/ $R_1r_1r_2r_2$/ $r_1r_1R_2r_2$) while the presence of dominant alleles at both the loci in homozygous or heterozygous condition ($R_1R_1R_2R_2$/ $R_1R_1R_2r_2$/ $R_1r_1R_2R_2$/ $R_1r_1R_2r_2$) would result in susceptibility.

The $F_2$ plants of the cross AP-127 × JI-35 segregated in the ratio of 9 (resistant): 7 (susceptible) indicating that two dominant genes with complementary interaction conferring resistance in AP-127. In case of AP-127, it is hypothesised that resistance to fusarium wilt is expressed when both the dominant genes are in homozygous or heterozygous conditions ($R_1R_1R_2R_2$/ $R_1R_1R_2r_2$/ $R_1r_1R_2R_2$/ $R_1r_1R_2r_2$) (Table 2). Two dominant complementary genes controlling fusarium wilt resistance were reported in previous studies in castor (Rao *et al.,* 2005; Shankar *et al.,* 2010; Shaw *et al.,* 2018), pigeonpea (Kumar *et al.,* 2009; Changaya *et al.*, 2012; Singh *et al.,* 2016) and safflower (Shivani and Varaprasad, 2016).

The genotypes AP-70 and AP-127 characterized in this study belong to the core set of germplasm identified at ICAR-IIOR (Sarada and Anjani, 2013) and they are genetically diverse (Senthilvel *et al.*, 2017). Therefore, these lines used can be utilized in future castor breeding programs to widen genetic base of castor inbred lines and hybrids.

## CONCLUSION

The wilt resistance in castor inbred lines AP-70 and AP-127 was controlled by two recessive genes with complementary interaction whereas it was controlled by two dominant genes with complementary interaction in other inbred line AP-127.

**Fig 1. Segregation of AP-70 × JI-35 $F_2$ population for Fusarium wilt**

**Table 2. Probable allelic combinations of parents, $F_1$ and $F_2$ genotypes of castor crosses studied for resistance to wilt**

| Cross | Parents | | $F_1$ | $F_2$* | |
|---|---|---|---|---|---|
| | Resistant | Susceptible | | Resistant | Susceptible |
| AP-163 × JI-35<br>AP-70 × JI-35 | $r_1r_1r_2r_2$ | $R_1R_1R_2R_2$ | $R_1r_1R_2r_2$<br>(Susceptible) | $R_1R_1r_2r_2$ (1)<br>$R_1r_1r_2r_2$ (2)<br>$r_1r_1R_2R_2$ (1)<br>$r_1r_1R_2r_2$ (2)<br>$r_1r_1r_2r_2$ (1) | $R_1R_1R_2R_2$ (1)<br>$R_1R_1R_2r_2$ (2)<br>$R_1r_1R_2R_2$ (2)<br>$R_1r_1R_2r_2$ (4) |
| AP-127 × JI-35 | $R_1R_1R_2R_2$ | $r_1r_1r_2r_2$ | $R_1r_1R_2r_2$<br>(Resistant) | $R_1R_1R_2R_2$ (1)<br>$R_1R_1R_2r_2$ (2)<br>$R_1r_1R_2R_2$ (2)<br>$R_1r_1R_2r_2$ (4) | $R_1R_1r_2r_2$ (1)<br>$R_1r_1r_2r_2$ (2)<br>$r_1r_1R_2R_2$ (1)<br>$r_1r_1R_2r_2$ (2)<br>$r_1r_1r_2r_2$ (1) |

*Values in parenthesis indicate frequency of genotypes having the particular allelic combination

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Research Article
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# EFFECT OF ORGANIC AND INORGANIC SOURCES OF NITROGEN ON YIELD ATTRIBUTES AND YIELD OF MAIZE UNDER SANDY LOAM SOIL CONDITIONS IN NORTHREN TELANGANA ZONE

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## ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station, Polasa, Jagtial during *kharif*, 2018 and 2019 to study the effect of integrated nutrient management practices on yield attributes and yield of maize. The experiment was laid out in a Randomized Block Design during *kharif*, 2018 with nine treatments comprising of $T_1$-100% RDF, $T_2$-75% RDN + 25% N through FYM, $T_3$-75% RDN + 25% N through vermicompost, $T_4$-75% RDN + 25% N through poultry manure, $T_5$-75% RDN+ 25% N through sheep manure, $T_6$-75% RDN + 25% N through neem cake, $T_7$-75 % RDN + *Azotobacter* @ 5 kg ha$^{-1}$, $T_8$-75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, $T_9$-75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$ replicated thrice. Significantly higher cob length, cob girth, number of rows cob$^{-1}$, number of kernels row$^{-1}$, number of kernels cob$^{-1}$, test weight (g), grain yield (kg ha$^{-1}$) and stover yield (kg ha$^{-1}$) were recorded. Among the different treatments, application of 75% RDN + 25% N through vermicompost recorded longest cobs (16.33 cm and 16.57 cm in 2018 and 2019, respectively), increased cob girth (15.23 cm and 16.00 cm in 2018 and 2019, respectively), registered higher kernel rows cob$^{-1}$ (13.37 and 15.00 in 2018 and 2019 respectively), number of kernels row$^{-1}$ (22.4 and 23.33 in 2018 and 2019 respectively), highest number of kernels cob$^{-1}$ (302 and 348 in 2018 and 2019, respectively) more test weight (30.57 and 30.07 in 2018 and 2019, respectively), more grain yield (6349 and 6514 kg ha$^{-1}$in 2018 and 2019, respectively) and stover yield (8259 and 8460 kg ha$^{-1}$ in 2018 and 2019, respectively) over 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$. While, it is comparable with 100 % RDF, 75 % RDN + 25% N through FYM and 75 % RDN + 25% N through sheep manure.

**Keywords:** Biofertilizers, maize, northern telangana, organic manures, yield attributes

Maize (*Zea mays L.*) is the world's third most important cereal crop after wheat and rice. It accounts to 8% and 25% of the world's total area and production, respectively under cereal crops. In India, maize occupies an area of 9.5 M. ha with an average production of 28.7 M. T with productivity of 3006 kg ha$^{-1}$, while in Telangana it is grown in an area of 0.56 M. ha with production of 2.99 M. T productivity of 5347 kg ha$^{-1}$ (CMIE, 2020).

Nutrient management in maize is one of the significant yield influencing character. The organic sources besides supplying N, P and K also make unavailable source of elemental nitrogen, bound phosphorus, micronutrients and decomposed plant residues into available form to facilitate plant to absorb the nutrients. But, the combined use of chemical fertilizers along with various organic sources is capable of improving soil quality and crop productivity on long term basis. As cropping system serves as a component of integrated nutrient management (INM) for sustaining the productivity of the system through efficient nutrient cycling, balanced fertilization must be based on the concept of the system as a whole rather than a single crop. Intensified and multiple cropping systems require judicious application of chemical, organic and bio-fertilizers for yield sustainability and improved soil health. Such integrated application is not only complementary but also has synergistic effects. Therefore, the nutrient needs of crop production systems can be met through integrated nutrient management and sustainable crop productivity, nutrient uptake and soil nutrient status in maize based cropping systems (Kemal and Abera, 2015).

## MATERIAL AND METHODS

A field experiment entitled "Effect of organic and inorganic sources of nitrogen on yield attributes and yield of maize under sandy loam soil conditions in Northren Telangana Zone" was conducted during *Kharif* 2018 and 2019 at Regional Agricultural Research Station, Polasa, Jagtial, Northern Telangana Zone of Telangana state. The soil of experimental site was sandy loam with pH of 7.7, Electrical conductivity

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0.23 dS $m^{-1}$, low in organic carbon (0.30 % ), low in available nitrogen (180 kg $ha^{-1}$) and medium in phosphorus (53 kg $ha^{-1}$) and medium in potassium (315 kg $ha^{-1}$).The experiment was laid out in a Randomized Block Design during *Kharif* 2018 and 2019 with nine treatments consisting of 100 % RDF, 75 % RDN + 25% N through FYM, 75 % RDN + 25% N through vermicompost, 75 % RDN + 25% N through poultry manure, 75 % RDN + 25% N through sheep manure, 75 % RDN + 25% N through neem cake, 75 % RDN + *Azotobacter* @ 5 kg $ha^{-1}$ ,75 % RDN + *Azospirillum*@ 5 kg $ha^{-1}$ and 75 % RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$ + *Azospirillum* @ 2.5 kg $ha^{-1}$. Crop was sown with a spacing of 60 cm x 20 cm on 27th June during 2018 and 26th June during 2019. Organic manures were applied (on equal N basis) as per the treatment and incorporated into the soil 30 days before sowing. Crop was fertilized with uniform level of 60 kg $P_2O_5$ and 50 kg $K_2O$ $ha^{-1}$. Half of the total N and full P and K fertilizers were applied at the time of sowing. Remaining N was applied at knee high stage by pocketing method and free living *Azotobacter* sp, *Azospirillum* sp were applied one day before sowing as per the treatments and incorporated into the soil. The required amount of N, P and K fertilizers was applied through Urea, SSP and Muriate of potash, respectively. Other cultural operations and plant protection measures were followed as per the recommendations. Crop received 603 mm (31 rainy days) and 746 mm (44 rainy days) rainfall during the crop growth period in 2018 and 2019, respectively.

## RESULTS AND DISCUSSION

### Yield attributes

### Cob length (cm)

The different levels of inorganic, organic and biofertilizers showed significant influence on the cob length of maize were presented in Table 1.

The significantly higher cob length (16.33 cm and 16.57 cm in 2018 and 2019, respectively) was obtained with the application of 75% RDN + 25% N through vermicompost and it was on par with that of 100% RDF (15.83 cm and 16.37 cm in 2018 and 2019, respectively), 75% RDN + 25% N through FYM (15.57 cm and 16.07 cm in 2018 and 2019, respectively) and 75% RDN + 25% N through sheep manure (14.90 cm and 15.70 cm in 2018 and 2019, respectively) and significantly superior to 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$ + *Azospirillum* @ 2.5 kg $ha^{-1}$, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$. The lower cob length (12.47 cm and 13.57 cm in 2018 and 2019, respectively) was recorded with application of 75% RDN + *Azotobacter* @ 5 kg $ha^{-1}$ during both the years.

The pooled data over the two years indicated that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher cob length (16.45 cm). However, it was on par with 100% RDF (16.10 cm), 75% RDN + 25% N through FYM (15.82 cm) and 75% RDN + 25% N through sheep manure (15.30 cm) and significantly superior to 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$+ *Azospirillum* @ 2.5 kg $ha^{-1}$.

Higher cob length with vermicompost, FYM and sheep manure in combination of chemical fertilizers might be due to greater availability of nutrient through combined application of organic and inorganic sources of nutrients. Enhanced availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased productive plants, cob girth, cob length and cob weight with these integrated nutrient management treatments.

The favorable effect of vermicompost FYM and sheep manure on growth might be attributed to presence of relatively readily available plant nutrients, growth enhancing substances and number of beneficial organisms like nitrogen fixing, phosphate solubilizing, cellulose decomposing and other beneficial microbes as well as antibiotics, vitamins and hormones etc. similar results were also reported by Dadarwal *et al*. (2009), Thavaprakaash and Velayudham (2007).

### Cob girth (cm)

The different levels of inorganic, organic and biofertilizers showed significant influence on the cob girth were presented in Table 1.

Significantly increased cob girth (15.23 cm and 16.00 cm in 2018 and 2019, respectively) were observed with the application of 75% RDN + 25% N through vermicompost and it was on par with that of 100% RDF (14.67 cm and 15.73 cm in 2018 and 2019, respectively), 75% RDN + 25% N through FYM (14.37 cm and 15.63 cm in 2018 and 2019, respectively) and 75% RDN + 25% N through sheep manure (14.33 cm and 15.37 cm in 2018 and 2019, respectively) and significantly superior to 75 % RDN + 25% N through poultry manure, 75 % RDN + 25% N through neem cake, , 75 % RDN + *Azospirillum* @ 5 kg ha$^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$. The lowest cob girth (11.90 cm and 13.13 cm in 2018 and 2019, respectively) was recorded with application of 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$ during both the years (Table 1).

The pooled data over two years indicated that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher cob girth (15.62 cm). However, it was on par with 100% RDF (15.20 cm), 75% RDN + 25% N through FYM (15.00 cm) and 75% RDN + 25% N through sheep manure (14.85 cm) and significantly superior to 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum*@ 5 kg ha$^{-1}$, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$+ *Azospirillum* @ 2.5 kg ha$^{-1}$.

Maximum cob girth with application of vermicompost, FYM and sheep manure in combination with inorganic fertilizers might be due to increased cell expansion and various metabolic processes in the presence of adequate available nutrients. These findings were in conformity with the results of Verma *et al.* (2012) and Ravi *et al.* (2012).

**Table 1. Yield attributes of maize crop as influenced by different organic and inorganic sources**

| Treatments | Cob length (cm) | | | Cob girth (cm) | | |
|---|---|---|---|---|---|---|
| | 2018 | 2019 | pooled | 2018 | 2019 | pooled |
| $N_1$- 100 % RDF | 15.83 | 16.37 | 16.10 | 14.67 | 15.73 | 15.20 |
| $N_2$-75 % RDN + 25% N through FYM | 15.57 | 16.07 | 15.82 | 14.37 | 15.63 | 15.00 |
| $N_3$-75 % RDN + 25% N through Vermicompost | 16.33 | 16.57 | 16.45 | 15.23 | 16.00 | 15.62 |
| $N_4$-75 % RDN + 25% N through Poultry manure | 14.27 | 14.53 | 14.40 | 13.57 | 13.93 | 13.75 |
| $N_5$-75 % RDN + 25% N through Sheep manure | 14.90 | 15.70 | 15.30 | 14.33 | 15.37 | 14.85 |
| $N_6$-75 % RDN + 25% N through Neem cake | 14.20 | 14.23 | 14.22 | 13.50 | 13.87 | 13.68 |
| $N_7$-75 % RDN + *Azotobacter* @ 5 kg ha$^{-1}$ | 12.47 | 13.57 | 13.02 | 11.90 | 13.13 | 12.52 |
| $N_8$-75 % RDN + *Azospirillum* @ 5 kg ha$^{-1}$ | 14.07 | 14.17 | 14.12 | 12.97 | 13.52 | 13.24 |
| $N_9$-75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$ | 14.10 | 14.20 | 14.15 | 13.00 | 13.73 | 13.37 |
| SEm $\pm$ | 0.93 | 0.92 | 0.78 | 0.69 | 0.85 | 0.62 |
| CD @ 5% | 1.97 | 1.95 | 1.65 | 1.46 | 1.80 | 1.31 |

**Number of kernel rows cob$^{-1}$**

The number of kernel rows cob$^{-1}$ of maize as influenced by different levels of inorganic, organic and biofertilizers is presented in Table 2.

The crop applied with 75% RDN + 25% N through vermicompost had significantly higher kernel rows cob$^{-1}$ (13.37 and 15.00 in 2018 and 2019 respectively). However, it was on par with 100% RDF (13.00 and 14.59 in 2018 and 2019, respectively), 75% RDN + 25% N through FYM (12.87 and 14.17 in 2018 and 2019, respectively) and 75% RDN + 25% N through sheep manure (12.67 and 14.02 in 2018 and 2019, respectively) and significantly superior to 75% RDN + 25% N through poultry manure, 75% RDN +

**Table 2. Yield attributes of maize crop as influenced by different organic and inorganic sources**

| Treatments | No. of kernal rows $cob^{-1}$ | | | No. of kernals $rows^{-1}$ | | | No. of kernals $cob^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | pooled | 2018 | 2019 | pooled | 2018 | 2019 | pooled |
| $N_1$- 100 % RDF | 13.00 | 14.59 | 13.80 | 22.17 | 22.67 | 22.42 | 287 | 332 | 309 |
| $N_2$-75 % RDN + 25% N through FYM | 12.87 | 14.17 | 13.44 | 20.57 | 21.40 | 20.98 | 264 | 304 | 282 |
| $N_3$-75 % RDN + 25% N through Vermicompost | 13.37 | 15.00 | 14.19 | 22.40 | 23.33 | 22.87 | 302 | 348 | 325 |
| $N_4$-75 % RDN + 25% N through Poultry manure | 11.83 | 12.57 | 12.04 | 19.67 | 20.20 | 19.55 | 232 | 254 | 236 |
| $N_5$-75 % RDN + 25% N through Sheep manure | 12.67 | 14.02 | 12.94 | 20.53 | 20.80 | 20.70 | 260 | 292 | 268 |
| $N_6$-75 % RDN + 25% N through Neem cake | 11.69 | 12.27 | 11.88 | 19.53 | 19.67 | 19.38 | 227 | 243 | 231 |
| $N_7$-75 % RDN + *Azotobacter* @ 5 kg $ha^{-1}$ | 10.80 | 11.47 | 11.00 | 18.43 | 18.60 | 18.18 | 199 | 213 | 200 |
| $N_8$-75 % RDN + *Azospirillum*@ 5 kg $ha^{-1}$ | 11.10 | 11.66 | 11.28 | 18.67 | 19.00 | 18.67 | 207 | 222 | 210 |
| $N_9$-75 % RDN + *Azotobacter* @2.5 kg $ha^{-1}$+ *Azospirillum* @ 2.5 kg $ha^{-1}$ | 11.53 | 12.05 | 11.67 | 19.00 | 19.53 | 19.17 | 217 | 234 | 223 |
| SEm $\pm$ | 0.69 | 0.97 | 0.58 | 1.19 | 1.40 | 0.86 | 21 | 29 | 18 |
| CD @ 5% | 1.46 | 2.06 | 1.23 | 2.52 | 2.97 | 1.82 | 44 | 61 | 38 |

25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$ , 75 % RDN + *Azospirillum* @ 5 kg $ha^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$ + *Azospirillum* @ 2.5 kg $ha^{-1}$ treatments during 2018 and 2019. On the other hand, significantly lowest number of kernel rows $cob^{-1}$ was recorded with treatment combination of 75% RDN + *Azotobacter* @ 5 kg $ha^{-1}$ (10.80 and 11.47 in 2018 and 2019 respectively).

The pooled data over two years indicated that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher kernel rows $cob^{-1}$ (14.19). However, it was on par with 100 % RDF (13.80) and 75% RDN + 25% N through FYM ( 13.44) and significantly superior to 75% RDN + 25% N through sheep manure, 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$+ *Azospirillum* @ 2.5 kg $ha^{-1}$.

The maximum number of kernel rows $cob^{-1}$ might be due to more availability of nutrients which led to the increased leaf area per plant and maintenance of photosynthetically active leaf area for longer duration and ultimately ended up availability of enough photosynthates to fulfill all the rows. These findings corroborate with the results of Wagh (2002), Singh and Nepalia (2009).

**Number of kernels $row^{-1}$**

The number of kernels $row^{-1}$ as influenced by different levels of inorganic, organic and biofertilizers of maize were presented in Table 2.

The optimum application of nutrients 75% RDN + 25% N through vermicompost had resulted in production of significantly highest number of kernels $row^{-1}$ (22.40 and 23.33 in 2018-19 and 2019-20 respectively) over 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75 % RDN + *Azotobacter* @ 2.5 kg $ha^{-1}$ + *Azospirillum* @ 2.5 kg $ha^{-1}$, 75% RDN + *Azospirillum* @ 5 kg $ha^{-1}$, 75% RDN + *Azotobacter* @ 5 kg $ha^{-1}$. While, it is comparable with 100 % RDF (22.17 and 22.67 in 2018 and 2019 respectively), 75% RDN + 25% N through FYM (20.57 and 21.40 in 2018 and 2019 respectively) and 75% RDN + 25% N through sheep manure (20.53 and 20.80 in 2018 and 2019 respectively) during 2018 and 2019. On the other hand, significantly lowest number of kernels row$^{-1}$ (18.43 and 18.60 in 2018 and 2019 respectively) was recorded with the application of 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$ during both the years.

The pooled data revealed that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher number of kernels row$^{-1}$ (22.87). However, it was on par with 100% RDF (22.42) and significantly superior to 75% RDN + 25% N through FYM and 75% RDN + 25% N through sheep manure, 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$ and 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$.

Due to higher availability of nutrients, the leaves and stalks had reached their full size and metabolic activity of plant tissue was normally at peak levels without delay, the flowering parts emerged, rich pollination took place and fertilization of silk was completed. Nutrient deficiency might because of poor pollination and reduced the number of ovules that would be fertilized. These findings corroborated the results of Mehta *et al*., 2011.

**Number of kernels cob$^{-1}$**

The number of kernels cob$^{-1}$ as influenced by different levels of inorganic, organic and biofertilizers of maize were presented in Table 2.

During 2018 and 2019, significantly higher number of kernels cob$^{-1}$ (302 and 348 in 2018 and 2019, respectively) recorded with application of 75% RDN + 25% N through vermicompost which was comparable with 100% RDF (287 and 332 in 2018 and 2019, respectively), 75% RDN + 25% N through FYM (264 and 304 in 2018 and 2019, respectively) and 75% RDN + 25% N through sheep manure (260 and 292 in 2018 and 2019, respectively) and significantly superior to 75 % RDN + 25% N through poultry manure, 75 % RDN + 25% N through neem cake, 75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum*@ 2.5 kg ha$^{-1}$, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$. On the other hand, significantly lowest number of kernels cob$^{-1}$ (199 and 213 in 2018 and 2019, respectively) was recorded with the application of 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$ during both the years.

The pooled analysis of variance for statistical evaluation of mean performance over two years revealed that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher number of kernels cob$^{-1}$ (325). However, it was on par with 100% RDF (309) and significantly superior to 75% RDN + 25% N through FYM, 75% RDN + 25% N through sheep manure, 75 % RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75 % RDN + *Azospirillum* @ 5 kg ha$^{-1}$ and 75% RDN +*Azotobacter* @ 2.5kgha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$.

**Table 3. Test weight (g), shelling percentage of maize crop as influenced by different organic and inorganic sources**

| Treatments | Test weight (g) | | Shelling percentage (%) | |
|---|---|---|---|---|
| | 2018 | 2019 | 2018 | 2019 |
| $N_1$- 100 % RDF | 29.73 | 29.90 | 74.81 | 74.29 |
| $N_2$-75 % RDN + 25% N through FYM | 29.33 | 29.50 | 74.21 | 73.13 |
| $N_3$-75 % RDN + 25% N through Vermicompost | 30.57 | 30.07 | 75.48 | 74.99 |
| $N_4$-75 % RDN + 25% N through Poultry manure | 28.67 | 28.37 | 73.81 | 74.44 |
| $N_5$-75 % RDN + 25% N through Sheep manure | 29.23 | 28.70 | 74.40 | 74.25 |
| $N_6$-75 % RDN + 25% N through Neem cake | 28.40 | 28.30 | 72.81 | 73.38 |
| $N_7$-75 % RDN + *Azotobacter* @ 5 kg ha$^{-1}$ | 27.23 | 27.40 | 71.95 | 72.45 |
| $N_8$-75 % RDN + *Azospirillum*@ 5 kg ha$^{-1}$ | 27.73 | 28.07 | 72.23 | 72.76 |
| $N_9$-75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$ | 28.07 | 28.20 | 72.51 | 73.23 |
| SEm $\pm$ | 0.77 | 0.76 | 3.17 | 4.09 |
| CD @ 5% | 1.63 | 1.61 | NS | NS |

Optimum supply of nutrients throughout the crop growth period owing to the combination of organic and inorganic sources resulted in higher number of kernels cob$^{-1}$. These findings are in conformity with the results of Kaur *et al.*, 2020.

**Test weight (g)**

The test weight (g) as influenced by different levels of inorganic, organic and biofertilizers of maize were presented in Table 3.

During both the years of study, significantly more test weight was recorded with application of 75 % RDN + 25% N through vermicompost (30.57 and 30.07 in 2018 and 2019, respectively) which was comparable with 100 % RDF (29.73 and 29.90 in 2018 and 2019, respectively), 75 % RDN + 25% N through FYM (29.33 and 29.50 in 2018 and 2019, respectively) and 75 % RDN + 25% N through sheep manure (29.23 and 28.70 in 2018 and 2019, respectively) and significantly superior to 75% RDN + 25% N through poultry manure, 75 % RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$ and 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$ (27.23 and 27.40 in 2018 and 2019, respectively) which inturn recorded the lowest test weight.

The supply of all essential nutrients from added sources especially from vermicompost, farmyard manure and sheep manure would have been used by the crop for producing the bold kernels. This might be due to the reason that vermicompost or FYM or sheep manure with its comparatively slower oxidisable nature might have released the nutrients slowly up to maturity stage of crop which accounted for better mobilization of nutrients to seeds thereby enhancing the seed weight. Similar findings were also reported by Tetarwal *et al.* (2011).

**Shelling percentage (%)**

The shelling percentage as influenced by different levels of inorganic, organic and biofertilizers furnished in Table 3. During both the years of study, no significant difference in shelling percentage was observed among different treatments.

**Table 4. Grain yield, Stover yield and Harvest index of maize as influenced by different organic and inorganic sources**

| Treatments | Grain yield (kg ha$^{-1}$) | | | Stover yield (kg ha$^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | Pooled | 2018 | 2019 | Pooled | 2018 | 2019 | Pooled |
| $N_1$- 100 % RDF | 6262 | 6342 | 6302 | 8166 | 8340 | 8253 | 43.38 | 43.18 | 43.28 |
| $N_2$-75 % RDN + 25% N through FYM | 6007 | 6211 | 6109 | 8065 | 8270 | 8168 | 42.67 | 42.86 | 42.76 |
| $N_3$-75 % RDN + 25% N through Vermicompost | 6349 | 6514 | 6431 | 8259 | 8460 | 8359 | 43.45 | 43.52 | 43.48 |
| $N_4$-75 % RDN + 25% N through Poultry manure | 5369 | 5557 | 5463 | 7282 | 7544 | 7413 | 42.45 | 42.44 | 42.44 |
| $N_5$-75 % RDN + 25% N through Sheep manure | 5424 | 5630 | 5527 | 7321 | 7867 | 7594 | 42.57 | 41.70 | 42.13 |
| $N_6$-75 % RDN + 25% N through Neem cake | 5151 | 5326 | 5239 | 7134 | 7441 | 7287 | 41.94 | 41.72 | 41.83 |
| $N_7$-75 % RDN + *Azotobacter* @ 5 kg ha$^{-1}$ | 4545 | 4642 | 4594 | 6395 | 6858 | 6627 | 41.43 | 40.34 | 40.89 |
| $N_8$-75 % RDN + *Azospirillum* @ 5 kg ha$^{-1}$ | 4816 | 4981 | 4898 | 6870 | 6917 | 6894 | 41.28 | 41.95 | 41.62 |
| $N_9$-75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$+*Azospirillum* @ 2.5 kg ha$^{-1}$ | 4973 | 5067 | 5020 | 6968 | 7141 | 7055 | 41.64 | 41.36 | 41.50 |
| Mean | 5433 | 5586 | 5509 | 7384 | 7649 | 7517 | 42.31 | 42.12 | 42.21 |
| SEm $\pm$ | 440 | 436 | 368 | 563 | 533 | 479 | 1.12 | 1.20 | 1.09 |
| CD @ 5% | 934 | 924 | 780 | 1194 | 1131 | 1015 | NS | NS | NS |

## YIELD

### Grain yield (kg ha$^{-1}$)

The data on grain yield of maize in response to different integrated nitrogen management treatments were presented in Table 4.

During both the years of study, significantly higher grain yield of maize was recorded with application of 75% RDN + 25% RDN through vermicompost (6349 and 6514 kg ha$^{-1}$) which was on par with 100% RDF (6262 and 6342 kg ha$^{-1}$), 75% RDN + 25% RDN through FYM (6007 and 6211 kg ha$^{-1}$) and 75% RDN + 25% RDN through sheep manure (5424 and 5630 kg ha$^{-1}$) during 2018 and 2019, respectively over 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$ + *Azospirillum* @ 2.5 kg ha$^{-1}$, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$(4545 and 4642 kg ha$^{-1}$ during 2018 and 2019, respectively), which in turn recorded lower grain yield.

The pooled data over two years indicated that the crop applied with 75% RDN + 25% N through vermicompost had significantly higher grain yield of maize (6431 kg ha$^{-1}$). However, it was on par with 100% RDF (6302 kg ha$^{-1}$), 75% RDN + 25% N through FYM (6109 kg ha$^{-1}$) and 75% RDN + 25% N through sheep manure (5527 kg ha$^{-1}$) and significantly superior to 75% RDN + 25% N through poultry manure, 75% RDN + 25% N through neem cake, 75% RDN + *Azospirillum* @ 5 kg ha$^{-1}$, 75 % RDN + *Azospirillum* @ 5 kg ha$^{-1}$ and 75 % RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$+ *Azospirillum* @ 2.5 kg ha$^{-1}$.

Maize applied with the recommended level of 200:60:50 kg ha$^{-1}$ NPK produced 6262 kg ha$^{-1}$ grain yield in 2018 and 6342 kg ha$^{-1}$ in 2019, respectively. This response was incident on sandy loam soil having a very low organic carbon content of 0.28% in the first year and 0.30% in the second year. The soil available nitrogen was also low. A plethora of literature confirmed that the present-day requirement of nitrogen is as high as 200-400 kg ha$^{-1}$ in nitrogen starving soils (Leela Rani *et al*., 2011, Imran *et al*., 2015 and Wang *et al.,* 2020). In his review Shaik Mohammad (2020) prompted that the excess and inappropriate application of fertilizers to improve crop production leads to an uncontrolled release of undesirable substances-nutrients and toxins in the soil, atmosphere, ground and surface waters. This is not safe for health. The soils have become sick and continuously degraded. The massive application of fertilizers and insufficient animal or green manures made the soils dusty and susceptible to erosion washing away the nutrients. Efforts to increase food grain production by the application of high doses of fertilizers with imbalanced nutrient proportions to the new high yielding varieties disrupted the equilibrium of native nutrient fertility. Rehm (2018) pointed that the green revolution varieties have a weakness. They cannot absorb as much nitrogen as the traditional varieties.

The results in the present investigation showed that the substitution of 25% recommended level of nitrogenous fertilizer with farm yard manure, vermicompost, sheep manure or poultry manure are the best options to realize similar yield as with the entire recommended level of nitrogen. This trend was consistent in both the years. But the pooled analysis of variance did not maintain this consistency with the integration of sheep or poultry manure. The effect of other sources of organic complements was not effective. The substitution of 25% nitrogenous fertilizer with neem cake or the addition of *Azotobacter* and *Azospirillum* @ 5 kg ha$^{-1}$ each and their combined application @ 2.5 kg ha$^{-1}$ each significantly reduced the yield of maize both in 2018 and 2019. The response of bacterial cultures *Azotobacter* and *Azospirillum* were highly inconsistent ranging from a positive to no response in previous investigations made by Kamlakannan *et al.* (2019).

Adequate supply of NPK in the early stages of a plant is considered very important in promoting rapid vegetative growth and in increasing sink in terms of flowering and seed setting, including their development. Thus, overall improved growth coupled with increased net photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structure on the other hand, might have improved the grain and stover yield (Abayomi *et al*., 2008)

### Stover yield (kg ha$^{-1}$)

The data on stover yield of maize in response to different integrated nutrient management treatments in relation to the recommended level of inorganic fertilizers presented in Table 4.

During both the years of study, significantly higher stover yield of maize was recorded with application of 75% RDN + 25% RDN through vermicompost (8259 and 8460 kg ha$^{-1}$) which is comparable with 100% RDF (8166 and 8340 kg ha$^{-1}$), 75% RDN + 25% RDN through FYM (8065 and 8270 kg ha$^{-1}$), 75% RDN + 25% RDN through sheep manure (7321 and 7867 kg ha$^{-1}$), 75% RDN + 25% RDN through poultry manure (7282 and 7544 kg ha$^{-1}$) and 75% RDN + 25% RDN through neem cake (7134 and 7441 kg ha$^{-1}$) during 2018 and 2019, respectively over 75% RDN + *Azotobacter* @ 2.5 kg ha$^{-1}$+ *Azospirillum*@ 2.5 kg ha$^{-1}$, 75% RDN + *Azospirillum*@ 5 kg ha$^{-1}$, 75 % RDN + *Azotobacter* @ 5 kg ha$^{-1}$, 75% RDN + *Azotobacter* @ 5 kg ha$^{-1}$ (6395 and 6858 kg ha$^{-1}$ during 2018 and 2019, respectively which in turn recorded the lower stover yield

Higher stover yield under levels of fertilizer and organic sources *viz*., vermicompost, FYM, sheep manure were due to higher plant height, LAI, dry matter accumulation, more nutrient availability and uptake by maize. These results are in conformity with the results of Singh and Nepalia (2009).

### Harvest Index (%)

During kharif of both the years (2018 & 2019), the harvest index of maize crop fertilized with different levels of inorganic and organic sources were furnished in the Table 4. There was no significant difference observed among different treatments in harvest index (%) during both the years of study.

## CONCLUSION

Based on the research results, it can be concluded that the integrated nutrient management through FYM, vermicompost, sheep manure by replacing 50 kg N ha$^{-1}$ out of the 200 kg recommended dose ha$^{-1}$ to maize produced similar yield attributes *viz.*, cob length, cob girth, no. of kernel rows cob$^{-1}$, no. of kernels row$^{-1}$, no.of kernels cob$^{-1}$, test weight (g), grain yield (kg ha$^{-1}$) and stover yield (kg ha$^{-1}$) as compared to the application of entire nitrogen through inorganic fertilizer. Hence it is evident that 25% of inorganic nitrogen can be substituted by organic manures *viz*., vermicompost, FYM, sheep manure to obtain on par yield in maize crop.

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# FACTORS INFLUENCING THE MANAGERIAL ABILITY OF FARMERS WITH REFERENCE TO MARKET LED EXTENSION IN TELANGANA

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## ABSTRACT

A research study was conducted to identify the factors influencing the managerial ability and obtain their strategic suggestions for enhancing the market led extension activities. Expost facto research design was followed and selected 140 respondents by multistage random sampling method. Unavailability of inputs at right time (95.71%) was major technical factor influencing the managerial ability of farmers followed by lack of adequate extension support and technical guidance in recommended practices (93.57%). Regarding Economic factors high cost of labour during harvesting (97.14%) was ranked first followed by High cost of plant protection chemicals, fertilizers and manures (94.28%) was second major influencing factor. Under the Market factors, Higher market price fluctuations/ non-remunerative prices/ less profit due to low market price (97.145) was ranked first followed by Lack of minimum physical facilities /market infrastructure facilities at APMC (94.28%) was ranked second. Regarding environmental factors 'Highly fluctuating weather conditions /loss of produce due to climate change or heavy rains (97.86%) was ranked first followed by 'Attack by insects and pests/ heavy incidence of diseases/heavy incidence of storage grain pest' (90.005) was ranked second. Major suggestions expressed by the farmers were ensure timely availability and adequate quantity of quality inputs by the Government, fix the minimum labor charges by the government or provide Agricultural machinery on subsidy basis so that labour problem can be minimized, Government should establish the cold storages besides the APMCs so when the price was low he can store his crop produce or provide pledge finance on crop produce to the farmers and Claiming of crop insurance should be easier due in natural calamity.

**Keywords:** Economic and Technical Factors, Managerial ability of farmers, Market led Extension

India has made many strides on production front but awfully lacking in the field of Agricultural Marketing. These inadequacies are becoming more acute with the significant changes taking place in Agri-food systems in domestic and overseas markets; the attainment of competitiveness is becoming increasingly dependent on the capacity of the country to develop effective and efficient agricultural marketing. Presently agricultural marketing system in India suffers from number of constraints which are either infrastructure related or government regulation related or technology related or related to poor information on domestic and overseas markets and opportunities or related to unstable and uncertain produce prices or related to delayed and late payment to producers and finally related to low producer's realization (Planning Commission Government of India, 2011).

Market led Extension is the market ward orientation of agriculture through extension includes Agriculture & Economics is the perfect blend for reaching at the door steps of farming community with the help of appropriate technology (Kaleel, 2007). Market led Extension is market oriented extension system which informs, stimulates and guides the farmer's right from selection of an enterprise to marketing of the produce with the purpose to get optimum return out of the enterprise. Market-led-extension works with various aspects on quality, consumer's preference, latest knowledge of market, market analysis, market intelligence, processing, and value addition, Use of ICTs and Appropriate Extension Approaches and other marketing information on regular basis. These helps the farmers to realize high returns for their produce, minimize the production costs, reduce the post-harvest loses and improve the product value and marketability. The extension system now needs to be oriented with knowledge and skills related to the market. To accomplish efficient marketing, the infrastructure like information and extension services to farmers, transport and communication facilities, public utility supply, trade and advertisement, public storage, market and abattoir facilities are very much required. (Duraisamy, 2007).

Accessibility of price information is of crucial relevance to inform farmer cash price expectation.

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**Table 1. Distribution of farmers based on Technical factors influencing the managerial ability and suggestions to overcome them** (n=140)

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | Unavailability of inputs including seeds, fertilizer, insecticides and pesticide at right time. | 134 | 95.71 | I | Ensure timely availability and adequate quantity of quality inputs by the Government. | 134 | 95.71 | I |
| 2 | Lack of information about high yielding varieties and their seed/planting materials availability | 128 | 91.42 | IV | Government has to supply the high yielding varieties/planting materials to the farmers through KVKs/DAATTC/AOs | 128 | 91.42 | IV |
| 3 | Difficulties or lack of skills in following the recommended practices | 124 | 88.57 | VI | The extension officers and scientists of KVKs conduct regular field visits and clear difficulties of farmers while following the recommended practices. | 124 | 88.57 | VI |
| 4 | Lack of adequate extension support and technical guidance in recommended | 131 | 93.57 | II | Conduct field visits regularly by the AOs, AEOs and scientists of KVK and provide technical guidance to the farmers | 131 | 93.57 | II |
| 5 | Lack of storage facilities at home | 130 | 92.86 | III | Knowledge may be imparted to the farmers on different traditional storage methods preparation at home | 130 | 92.86 | III |
| 6 | Lack of knowledge in Post-harvest technology of crops/ Higher post-harvest losses | 126 | 90.00 | V | Conduct awareness and training programmes to the farmers on importance of post-harvest management of crops by AOs and Scientist of KVKs | 126 | 90.00 | V |
| 7 | Lack of processing facilities in rural areas | 78 | 55.71 | VIII | Government should take initiative to start small scale processing units in rural areas | 78 | 55.71 | VIII |
| 8 | Lack of trainings on market led extension or market oriented Agriculture activities | 118 | 84.28 | VII | Conduct training programmes on market led extension or market oriented Agriculture activities the farmers and improve their knowledge | 118 | 84.28 | VII |
| 9 | Inadequate supply of electricity | 57 | 40.71 | IX | As per allotted time slot TSSPDCL should supply electricity | 57 | 40.71 | IX |

Pooled information could be reliable, trusted and understandable, and the cost of information should be within the capacity of farmers. Information should improve their marketing decisions, negotiation, and price realization. As physical barriers, such as road condition and vehicle arrangement for transporting the produce might deter their access to the right place, they need to be market-oriented and skilled in calculating returns for risks they take. In this regard state Agricultural department in association with Agricultural Produce Market Committee's (APMC) officials, commodity exchanges, and technology service providers could take the initiative of real-time price dissemination through in-call or SMS-based services to the farmers (Tadesse and Bahiigwa, 2015).

## MATERIAL AND METHODS

The present study confined to an *Ex-post-facto* research design. The state of Telangana selected purposively for current study. Northern Telangana Zone was selected purposively for current study because more number of APMCs were present and they were in functional stage compare to Central and South Telangana zones. Out of 12 districts present in Northern Telangana zone, 7 districts were selected randomly. From each district 2 APMCs were selected randomly thus a total 14 APMC were selected for the current study. Two villages from each district were selected randomly based on the location of APMC in the district. 14 villages were selected randomly for the study located within the 15 km and 15 to 20 km of radius of APMC. From each district 20 farmers, constituting total 140 farmers were selected randomly as respondents for the current study.

Factors influencing refers as situations or circumstances which impede, confine or restrict the activity or performance of an individual. This objective of the present study was focused on factors influencing the managerial ability of farmers for Market led extension which may also in form of difficulties, constraints, and bottleneck of farmer activities related to farming and marketing. These may enforce the farmers to take certain decisions in the process of farming and marketing. Farm planning, planning of production, post-harvest management, APMC rules, market demand, market situation, farmers need, whether to sell produce or not, when to sell, time, choice of place, marketing channel and others were taken into account during the analyzing the factors influencing the managerial ability.

## RESULTS AND DISCUSSION

### Factors influencing the managerial ability of farmers

The data presented in the table 1 and figure 1 indicates that out of several technical factors influencing the farmers while farming and marketing, Unavailability of inputs at right time (95.71%) was considered major and ranked first followed by Lack of adequate extension support and technical guidance in recommended practices (93.57%) as second, 'Lack of storage facilities at home' (92.86%) ranked third, Lack of information

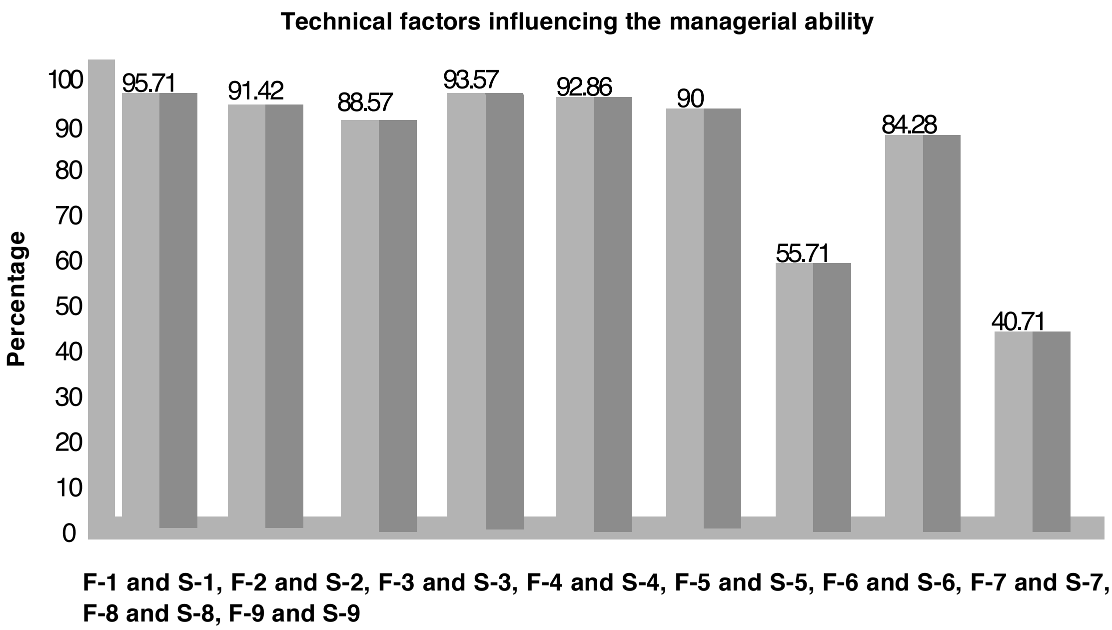


**Figure 1. Distribution of farmers based on Technical factors influencing the managerial ability and suggestions to overcome them**

about high yielding varieties and their seed/planting materials availability (91.42%) ranked fourth, Lack of knowledge in Post-harvest technology of crops/ Higher post-harvest losses (90.00%) ranked fifth, Difficulties or lack of skills in following the recommended practices (88.57%) ranked sixth, Lack of trainings on market led extension or market oriented agriculture activities (84.28) ranked seventh, Lack of processing facilities in rural areas (55.71%) ranked eighth and Inadequate supply of electricity (40.71%) ranked ninth.

The suggestions offered by farmers to overcome the technical factors influencing the managerial ability for Market led extension were collected and ordered on their intensity with rank order. Majority of the farmers reported that 'Ensure timely availability and adequate quantity of quality inputs by the Government' was ranked first followed by 'Conduct field visits regularly by the AOs, AEOs and scientists of KVK and provide technical guidance to the farmers' (II Rank), Knowledge may be imparted to the farmers on different traditional storage methods preparation at home (III Rank), Government has to supply the high yielding varieties/planting materials to the farmers through KVKs/DAATTC/AOs (IV Rank), Conduct awareness and training programmes to the farmers on importance of post-harvest management of crops by AOs and Scientist of KVKs (V Rank), The extension officers and scientists of KVKs conduct regular field visits and clear the difficulties of farmers while following the recommended practices (VI Rank), Conduct training programmes on market led extension or market oriented agriculture activities of the farmers and improve their knowledge (VII Rank), Government should take initiative to start small scale processing units in rural areas (VIII Rank) and As per allotted time slot TSSPDCL should supply electricity (IX Rank).

The data presented in the table 2 and figure 2 indicates that the Economic factors 'High cost of labour during harvesting' was ranked (97.14%) first followed by 'High cost of plant protection chemicals, fertilizers and manures' (94.28%) ranked second. 'Delay in implementation of Government development programmes or schemes' was ranked third (III Rank), Lack of skilled labour availability during harvesting, grading and processing time ranked fourth (IV Rank), Inadequate availability of credit/ Unawareness of credit facilities of government ranked fifth (V Rank), Difficulties or lack of skills in following the recommended practices ranked sixth (VI Rank), Lack of trainings on market oriented Agriculture activities ranked seventh (VII Rank), Lack of subsidies on inputs ranked eighth (VIII Rank), Higher cost of cultivation of crops ranked ninth (IX Rank), Lack of government support during crop failure ranked tenth (X Rank) and Unavailability of Agricultural machinery on hire basis was ranked eleven (XI Rank).

Suggestions regarding economic factors 'Fix the minimum labor charges by the government or provide Agricultural machinery on subsidy basis so that labour problem can be minimized' was ranked first (97.14%) followed by "Educate the farmers to follow

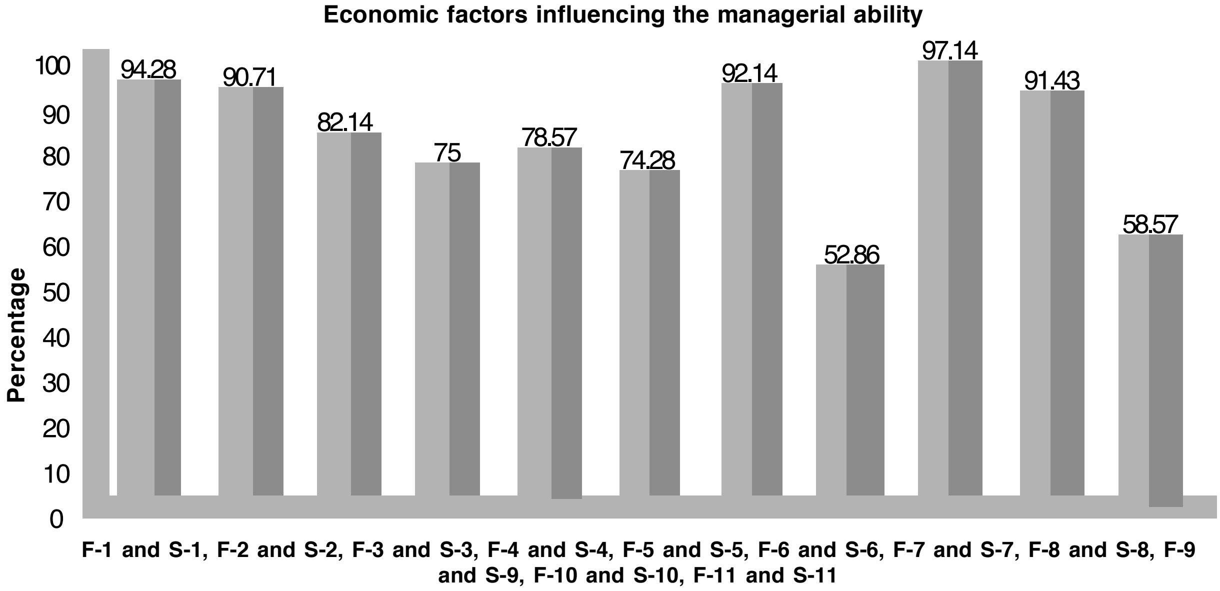


**Figure 2. Distribution of farmers based on Economic factors influencing the managerial ability and suggestions to overcome them**

**Table 2. Distribution of farmers based on Economic factors influencing the managerial ability and suggestions to overcome them** (n=140)

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | High cost of plant protection chemicals, fertilizers and manures | 132 | 94.28 | II | Educate the farmers to follow recommended doses of fertilizers and pesticides. Motivate the farmers to follow IPM in different crops | 132 | 94.28 | II |
| 2 | Inadequate availability of credit/ Unawareness of credit facilities of government | 127 | 90.71 | V | Crop loan/ credit facilities should be easily available to the farmers | 127 | 90.71 | V |
| 3 | Lack of awareness about Government price policies and schemes related market. | 115 | 82.14 | VI | Department of Agriculture and KVKs/DAATTC should conduct training/awareness programmes to the farmers on new programmes /schemes and price policies of government related to Agricultural Marketing | 115 | 82.14 | VI |
| 4 | Lack of subsidies on inputs | 105 | 75.00 | VIII | Inputs should be subsidized by the government/ Government should extend subsidies on inputs | 105 | 75.00 | VIII |
| 5 | Delay in payments by traders at Market | 110 | 78.57 | VII | Ensure immediate payments through the direct benefit transfer system | 110 | 78.57 | VII |
| 6 | Higher cost of cultivation of crops and margin | 104 | 74.28 | IX | MSP should be fixed on cost of production | 104 | 74.28 | IX |
| 7 | Delay in implementation of Government development programmes or schemes. | 129 | 92.14 | III | Government should take action and implement the programmes /schemes without any delay in rural areas | 129 | 92.14 | III |
| 8 | Unavailability of Agricultural machinery on hire basis | 74 | 52.86 | XI | Promote low cost farm mechanization/promote CHC in the villages | 74 | 52.86 | XI |
| 9 | High cost of labour during harvesting | 136 | 97.14 | I | Fix minimum labor charges by the government or provide Agricultural machinery on subsidy basis so that labour problem can be minimized | 136 | 97.14 | I |
| 10 | Lack of skilled labour availability during harvesting, Grading and processing time. | 128 | 91.43 | IV | Government should provide harvesting, grading and processing machinery on subsidy basis to decrease the labour problem | 128 | 91.43 | IV |
| 11 | Lack of government support during crop failure | 82 | 58.57 | X | Government should provide support during crop failure | 82 | 58.57 | X |

recommended doses of fertilizers and pesticides and motivate the farmers to follow IPM in different crops (94.28%) second. 'Government should take action and implement the programmes/schemes without any delay in rural areas' was ranked third (III Rank), Government should provide harvesting, grading and processing machinery on subsidy basis to decrease the labour problem ranked fourth (IV Rank), Crop loan/ credit facilities should be easily available to the farmers ranked fifth (V Rank), Department of Agriculture and KVKs/DAATTC should conduct training/awareness programmes to the farmers on new programmes/ schemes and price policies of government related to Agricultural Marketing ranked sixth (VI Rank), Ensure immediate payments through the direct benefit transfer system ranked seventh (VII Rank), Inputs should be subsidized by the government/Government should extend subsidies on inputs ranked eighth (VIII Rank), MSP should be fixed on cost of production and margin ninth (IX Rank), Government should provide support during crop failure ranked tenth (X Rank) and Promote low cost farm mechanization/promote CHC in the villages was ranked eleven (XI Rank).

The data presented in the table 3 Under the Market factors 'Higher market price fluctuations/non-remunerative prices/ Less profit due to low market price' was ranked first (97.14%) followed by 'Lack of minimum physical facilities / market infrastructure facilities at APMC' ranked second (II Rank). 'Collusion among the traders' was ranked third (III Rank), 'Non-availability of market information in time/ Lack of reliable market information' ranked fourth (IV Rank), 'Inadequate / absence of storage facilities at market' ranked fifth (V Rank), "Non cooperative nature of APMC officers during buying and selling activity' ranked sixth (VI Rank), 'Taking excess market charges by commission agents as arbitrary deduction in the sale amount of produce' ranked seventh (VII Rank), 'Lack of awareness about grading and different grades' ranked eighth (VIII Rank), 'Lack of drying platforms at APMC' ranked ninth (IX Rank), 'Some commission agents are favourable to buyer' ranked tenth (X Rank), 'Dominance of traders in the villages' ranked eleven (XI Rank), 'Lack of Government procurement agencies' ranked twelve (XII Rank), 'Monopolistic characteristics of traders /No chance to sell more commodities at market and Lack of cooperative marketing system in villages' ranked thirteen (XIII Rank), 'Existence of large number of intermediaries in marketing process' ranked fourteen (XIV Rank), 'High cost of transportation of crop produce to the market' ranked fifteen (XV Rank), 'Illegal deduction while selling the produce at market' ranked sixteen (XVI Rank) and 'Lack of covered sheds in the market to cover the crop produce' was ranked seventeen (XVII Rank).

'Middle man manipulate the situation/distress sale and Lack of marketing facilities at local place/ No nearby markets' was ranked eighteen (XVIII Rank), 'Lack of unity among the farmers while marketing the crop produce' and 'High cost of storage' ranked ninteen (XIX Rank), 'Lack of open auction at APMC' ranked twenty (XX Rank), 'Lack of suitable cold storage facilities' ranked twenty one (XXI Rank), 'Delay in the sale of crop produce at Mandi' ranked twenty two (XXII Rank) and 'Malpractices in weighing' was ranked twenty three (XXIII Rank). This is in conformity with results of Haneef Rifat *et al.,* 2019 and Rao (2019).

Suggestions under the Market factors 'Government should establish the cold storages besides the APMCs so when the price was low he can store his crop produce or Provide pledge finance on crop produce to the farmers' was ranked first (97.14%) followed by 'Create market infrastructure facilities/ Develop infrastructure on the basis of requirement at APMC' (II Rank), 'The behaviours of traders should be closely monitored by the APMCs for any intentional hoarding. To avoid collusion between traders, involvement of APMC officials in the auctioning process should be mandatory' ranked third (III Rank), 'Use of ICT to offer marketing information & extension activities/Display of prices at each market place/ marketing related information through mobile SMS' ranked fourth (IV Rank), 'Godown/warehouse facilities should made available by the Government to the farmers' ranked fifth (V Rank) and 'District market secretary should instruct the APMC officers to maintain good relation with the farmers and provide their support during buying and selling activity' was ranked sixth (VI Rank).

'Prevention of unauthorized deduction of produce by commission agents during sale of produce' was ranked seventh (VII Rank), 'Educate the farmers through conducting awareness or training programmes on grading and FAQ standards' ranked eighth (VIII Rank), 'Create market infrastructure facilities/ Develop

**Table 3. Distribution of farmers based on Market factors influencing the managerial ability and suggestions to overcome them**

(n=140)

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | Lack of covered sheds in the market to cover the crop produce | 82 | 58.57 | XVII | Government should provide the budget to the each APMCs to develop the required infra-structure facilities | 82 | 58.57 | XVII |
| 2 | Middlemen manipulate the situation / distress sale | 71 | 50.71 | XVIII | APMC officer should conduct village visits during harvesting time to control the distress sales in the villages | 71 | 50.71 | XVIII |
| 3 | Inadequate / absence of storage facilities at market | 124 | 88.57 | V | Godown/warehouse facilities should made available by the Government to the farmers | 124 | 88.57 | V |
| 4 | Collusion among the traders | 131 | 93.57 | III | The behaviours of traders should be closely monitored by the APMCs for any intentional hoarding.<br>To avoid collusion between traders, involvement of APMC officials in the auctioning process should be mandatory | 131 | 93.57 | III |
| 5 | Illegal deduction while selling the crop produce at market | 86 | 61.43 | XVI | APMC should monitor and assure charges as per norms. | 86 | 61.43 | XVI |
| 6 | Lack of Government procurement agencies | 106 | 75.71 | XII | Government should purchase or help the farmers in selling the crop produce | 106 | 75.71 | XII |
| 7 | Lack of minimum physical facilities / market infrastructure facilities at APMC | 132 | 94.28 | II | Create market infrastructure facilities/ Develop infrastructure on the basis of requirement at APMC | 132 | 94.28 | II |
| 8 | High cost of transportation of crop produce to the market | 92 | 65.71 | XV | Provide concession in transportation charges by the Traders/APMC | 92 | 65.71 | XV |
| 9 | Lack of drying platforms at APMC | 112 | 80.00 | IX | Develop infrastructure on the basis of requirement at APMC | 112 | 80.00 | IX |
| 10 | Lack of unity among the farmers while marketing the crop produce | 68 | 48.57 | XIX | Motivate the farmers through continuous field visits and awareness programmes and helping them to start to FPOs/cooperative societies in their villages | 68 | 48.57 | XIX |

(Table 3 cont.)

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 11 | Higher market price fluctuations/ non-remunerative prices/ Less profit due to low market price. | 136 | 97.14 | I | Government should establish the cold storages besides the APMCs so when the price was Provide pledge finance on crop produce to the farmers low he can store his crop produce. | 136 | 97.14 | I |
| 12 | Lack of open auction at APMC | 63 | 45.00 | XX | Open auction should be conducted in all the APMCs | 63 | 45.00 | XX |
| 13 | Non-availability of market information in time/ lack of reliable market information | 129 | 92.14 | IV | Use of ICT to offer marketing information & extension activities/Display of prices at each market place/ disseminate the marketing related information through mobile SMS | 129 | 92.14 | IV |
| 14 | Lack of marketing facilities at local place/ No nearby markets | 71 | 50.71 | XVIII | Government should motivate the farmers for adopting the group marketing/Promote farmers Producer organization (FPOs) in the villages. Establishment of procurement centers in every village or nearby places | 71 | 50.71 | XVIII |
| 15 | Monopolistic characteristics of traders /No chance to sell more commodities at market | 102 | 72.86 | XIII | APMC should allow the Traders to buy more commodities on single license | 102 | 72.86 | XIII |
| 16 | Lack of awareness about grading and different grades | 114 | 81.43 | VIII | Educate the farmers through conducting awareness or training programmes on grading and FAQ standards | 114 | 81.43 | VIII |
| 17 | Lack of suitable cold storage facilities | 59 | 42.14 | XXI | Establishment of suitable cold storage facilities by the government in the rural areas | 59 | 42.14 | XXI |
| 18 | High marketing costs | 68 | 48.57 | XIX | In order to reduce marketing costs, it is suggested to reduce actors involved in the market, like promoting direct sales of farmers produce to wholesaler and more particularly linking small farmers produce to retail chains | 68 | 48.57 | XIX |
| 19 | Malpractices in weighing | 39 | 27.86 | XXIII | Introduction of properly and regularly calibrated weighing equipment's at market. Or use of electronic weighing machines at APMCs to eliminate Malpractices | 39 | 27.86 | XXIII |

(Table 3 cont.)

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 20 | Lack of cooperative marketing system in villages | 102 | 72.86 | XIII | Cooperative marketing societies may be created by the village farmers | 102 | 72.86 | XIII |
| 21 | Dominance of traders in the villages | 109 | 77.86 | XI | An APMC officer has to Control the buying activity of traders in the villages through conducting village visits in the harvesting time | 109 | 77.86 | XI |
| 22 | Existence of large number of intermediaries in marketing process | 96 | 68.57 | XIV | Government should bring the policies to reduce the number of intermediaries and at the same time provision could be made for direct sale by farmers to the consumer | 96 | 68.57 | XIV |
| 23 | Some commission agents are favourable to buyer | 111 | 79.28 | X | APMC office bearers closely monitor the buying and selling activity and control the malpractices of Traders and commission agents | 111 | 79.28 | X |
| 24 | Non cooperative nature of APMC officers during buying and selling activity | 119 | 85.00 | VI | District market secretary should instruct the APMC officers to maintain good relation with the farmers and provide their support during buying and selling activity | 119 | 85.00 | VI |
| 25 | Taking excess market charges by commission agents as arbitrary deduction in the sale amount of produce | 118 | 84.28 | VII | Prevention of unauthorized deduction of produce by commission agents during sale of produce | 118 | 84.28 | VII |
| 26 | Delay in the sale of crop produce at Mandi | 56 | 40.00 | XXII | APMC should focus on faster the sales of crop produce at APMC | 56 | 40.00 | XXII |

infrastructure on the basis of requirement at APMC' ranked ninth (IX Rank), 'APMC office bearers closely monitor the buying and selling activity and control the malpractices of Traders and commission agents' ranked tenth (X Rank) and 'APMC officers has to control the buying activity of traders in the villages through conducting village visits in the harvesting time' was ranked eleven (XI Rank).

'Many farmers felt that the government should purchase or help them in selling the crop produce' was ranked twelve (XII Rank), 'APMC should allow the Traders to buy more commodities on single license' and 'Cooperative marketing societies may be created by the village farmers' ranked thirteen (XIII Rank), 'Government should bring the policies to reduce the number of intermediaries and at the same time provision could be made for direct sale by farmers to the consumer' ranked fourteen (XIV Rank), 'Provide concession in transportation charges by the Traders/ APMC' ranked fifteen (XV Rank), 'APMC should monitor and assure charges as per norms' ranked sixteen (XVI Rank), 'Government should provide the budget to the each APMCs to develop the required infrastructure facilities' ranked seventeen (XVII Rank), 'APMC officer should conduct village visits during harvesting time to control the distress sales in the villages' and 'Government should motivate the farmers for adopting the group marketing/Promote farmers producer organization (FPOs) in the villages, 'Establishment of procurement centers in every village or nearby places' was ranked eighteen (XVIII Rank).

'Motivate the farmers through continuous field visits and awareness programmes and helping them to start to FPOs in their villages and in order to reduce marketing costs, it is suggested to reduce actors involved in the market, like promoting direct sales of farmers produce to wholesaler and more particularly linking small farmers produce to retail chains' was ranked nineteen (XIX Rank), 'Open auction should be conducted in all the APMCs' ranked twenty (XX Rank), 'Establishment of suitable cold storage facilities by the government in the rural areas' ranked twenty one (XXI Rank), 'APMC should focus on faster the sales of crop produce at APMCs' ranked twenty two (XXII Rank) and 'Introduction of properly and regularly calibrated weighing equipment's at market or use of electronic weighing machines at APMCs to eliminate malpractices' was ranked twenty three (XXIII Rank).

Regarding environmental factors 'Highly fluctuating weather conditions /Loss of produce due to climate change or heavy rains' was ranked first (97.86%) followed by 'Attack by insects and pests/ Heavy incidence of diseases/Heavy incidence of storage grain pest' (II Rank). 'Poor drainage or lack of irrigation facilities' ranked three (III Rank), 'Low soil fertility status' ranked four (IV Rank) and 'Excessive soil erosion' was ranked fifth (V Rank).

Suggestions regarding environmental factors 'Claiming of crop insurance should be easier due in natural calamity' was ranked first (97.86%) followed by 'Motivate the farmers to follow IPM in different crops' and 'The extension staff provide need based technical advices to the farmers to control pests and diseases' (II Rank). 'Irrigation canal should be extended up to unreached area/Restoration of water bodies through government interventions' was ranked third (III Rank), 'Identification of soil improving crops under major agro-climatic zone' ranked fourth (IV Rank) and 'Farmers plant trees, grass to cover and bind the soil. Herbs, wild flowers and small trees were best option' was ranked fifth (V Rank).

## CONCLUSION

The study shows that Technical, Economic, Market and Environmental factors which influencing the managerial ability of farmers for Market led extension. Major suggestions expressed by the farmers were ensure timely availability and adequate quantity of quality inputs by the Government, fix the minimum labor charges by the government or provide Agricultural machinery on subsidy basis so that labour problem can be minimized, Government should establish the cold storages besides the APMCs so when the price was low he can store his crop produce or provide pledge finance on crop produce to the farmers and Claiming of crop insurance should be easier due in natural calamity. These problems and suggestions need to be stressed so as to scale up the market led extension activities.

**Table 4. Distribution of farmers based on environmental factors influencing the managerial ability and suggestions to overcome them (n=140)**

| S.No | Influencing factors | F | % | Rank | Suggestions | F | % | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | Attack by insects and pests/ Heavy incidence of diseases/ Heavy incidence | 126 | 90.00 | II | Motivate the farmers to follow IPM in different crops. The extension staff provide need based technical advices to the farmers to control pests & diseases | 126 | 90.00 | II |
| 2 | Excessive soil erosion | 73 | 52.14 | V | Farmers plant trees and grass to cover and bind the soil. Herbs, wild flowers and small trees were best option | 73 | 52.14 | V |
| 3 | Poor drainage or lack of irrigation facilities | 121 | 86.43 | III | Irrigation canal should be extended up to unreached area/Restoration of water bodies through government interventions | 121 | 86.43 | III |
| 4 | Low soil fertility status | 99 | 70.71 | IV | Identification of soil improving crops under major agro climatic zone | 99 | 70.71 | IV |
| 5 | Highly fluctuating weather conditions / Loss of produce due to climate change or heavy rains | 137 | 97.86 | I | Claiming of crop insurance should be easier due in natural calamity | 137 | 97.86 | I |

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# EFFECT OF SOLVENT EXTRACTED KARANJ CAKE WITH ENZYMES AND LIVER TONIC SUPPLEMENTATION ON PERFORMANCE, NUTRIENT DIGESTIBILITY AND ECONOMICS OF BROILER CHICKEN

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## ABSTRACT

An experiment was conducted to evaluate the effect of dietary inclusion of solvent extracted karanj cake (SKC) and iso propyl alcohol (IPA) treated SKC supplemented with protease (4000 U/kg), phytase (400 U/kg) and liver tonic (0.1%) on performance, nutrient digestibility and returns over feed cost in broiler chickens. The inclusion of control and karanj cake were included in diets on isocaloric and isonitrogenous basis at graded (6%) level making 12 treatments (T1 to T12). A total of 360 day-old commercial broiler chicks, which were distributed in a randomized block design into 12 groups with 6 replicates of 5 chicks each. The chicks were housed in battery brooders and fed experimental diets from 1 to 42 days of age. The results revealed that inclusion of IPA treated karanj cake and SKC at 6% level treated with enzymes and liver tonic supplementation significantly did not improve the body weight gain, feed intake and feed conversion ratio compared to control groups. The percent retention of dry matter and crude protein were significantly ($P<0.05$) higher in control group compared with 6% SKC and IPA treated karanj cake with enzymes or liver tonic supplementation at 6$^{th}$ week of age. Mortality on karanj cake diets was within the limits. The 6% IPA treated karanj cake & SKC of the dietary treatments with or without supplementation of enzymes and liver tonic recorded returns over feed cost was lower compared to control. It can be concluded that, supplementation of enzymes / liver tonic could not alleviate the toxic effects of solvent extracted karanj cake or IPA treated karanj cake at 6% level in the diet.

**Keywords:** Broilers, enzymes, karanj cake, liver tonic, nutrient digestibility

The large gap between the availability and requirements of poultry feeds necessitated the exploration of alternate unconventional feeds in poultry rations. Karanj seeds are mainly used for oil extraction and the residue left after oil extraction is known as karanj cake. Two types of the cakes are available depending upon the type of extraction, namely expeller pressed and solvent extracted cake, which have good amount of protein used for animal feeding. The CP content of the cake is fairly rich and it generally varies from 22.0 to 28.7 and 30.0 to 38.0% in expeller and solvent extracted cakes, respectively (Paswan *et al*., 2020; Raj *et al*., 2016). However, raw karanj cake is not commonly used as a feed for poultry due to its poor intake and presence toxic factors, i.e. total tannins, phytate, karanjin and trypsin inhibitors and furanoflavones like Pongamol, Kanugin and Kanjone compounds. Feeding of karanj cake at higher levels adversely affected the performance due to the presence of toxic factors in the oil or oil fraction of the cake (Raju *et al.,* 2010). Detoxification of the karanj cake by removal/ neutralization of these toxic principles offers possible strategy for making it fit for use in poultry diet (Panda, 2004). Detoxification of karanj cake by various physico-chemical methods like solvent extraction, water washing, pressure cooking and alkaili and acid treatment reduced the toxic effects of karanj cake (Panda, 2004). Reddy *et al*. (2011) revealed that the expeller karanj cake with 0.2% methionine supplementation had resulted in improved performance and immunity in the commercial broilers up to 6 weeks of age.

Various treatments such as autoclaving, water washing, soaking, partial deoiling and alkali treatments have been tried to detoxify the karanj cake. However, none of these treatments appeared to make the processed cake completely safe, suitable and wholesome for animal feeding. Consequently, further efforts need to be made to evolve suitable method(s) of detoxification in order to convert karanj cake into a

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wholesome protein supplement, which would be used for poultry feeding. Keeping this background in view, the present investigation was carried out to study the possibility of decreasing the adverse effects of karanj cake through supplementation of enzymes/liver tonic in broilers diets.

## MATERIAL AND METHODS

The experiment was conducted from March 2016 to April 2017. A total of 360 day-old commercial male broiler (*Cobb* 400) chicks were procured, wing banded and weighed individually. The broiler pre starter (1-11 days), starter (12-21days) and finisher (22-42 days) diets were formulated to contain *iso-nitrogenous* and *iso-caloric*. Six replicates were allocated to each of the treatments (12), employing five birds/replicate. The chicks of the control group were fed diets containing soybean meal. In the test group diets, SKC and IPA processed SKC was incorporated at 6%. Further, protease, phytase or liver tonic were supplemented to each of the above diet. Thus in all, a total of 12 different diets were formulated. All the diets were *isonitrogenous* and *isocaloric* through the adjustment of other ingredients. The composition of karanj cake and IPA treated karanj cake was presented in Table 1.

**Table 1. Analysed percent proximate composition of various *Karanj* cakes**

| Nutrient | SKC | IPA treated SKC |
|---|---|---|
| Moisture | 8.51 | 7.53 |
| Dry matter | 91.49 | 92.47 |
| Ether Extract* | 5.64 | 4.77 |
| Total ash* | 3.39 | 4.09 |
| Crude Protein* | 29.96 | 31.19 |
| Crude fiber* | 5.86 | 4.76 |
| Calcium* | 2.33 | 1.67 |
| Total Phosphorus* | 0.52 | 0.50 |

* Values on percentage dry matter basis
SKC – Solvent extracted karanj cake
IPA – Isopropyl alcohol

The individual body weight of chicks and replicate-wise feed intake were recorded at weekly intervals throughout the experimental period and weekly feed conversion ratio was calculated. After completion of 42 days of experimentation, a metabolic trial of four days duration was conducted to determine the retention of various nutrients (DM, CP, EE and Total ash). Feed cost for live weight gain (kg) and returns over feed cost (Rs.) and gain/loss over control (Rs/bird) were calculated.

Data analyzed for mean, standard errors and analysis of variance as per method of Snedecor and Cochran (1989) and comparison of means were done using Duncan test (1955) using software of Statistical Package for Social Sciences (SPSS) 15.0 version and significance was considered at $P<0.05$.

## RESULTS AND DISCUSSION

Record of temperature was maintained on daily basis where the highest daily average temperature recorded is 40.02$^0$C and the lowest temperature is 35.5$^0$C during the experimental period.

### Body weight gain

The body weight gain was significantly ($P<0.05$) higher in the control group as compared to SKC and IPA treated SKC. However among the treatments, higher body weight gain was recorded with IPA treated SKC than the SKC. Supplementation of protease or phytase to 6% IPA treated SKC did not show any benefit in weight gain, but no change in weight gain was observed when liver tonic was supplemented to IPA treated SKC (Table 2). Supplementation of liver tonic with SKC and IPA treated SKC did showed significant difference on body weight gain at 42 days of age. The reduction in body weight gain with SKC and IPA treated karanj cake might be due to reduced feed intake and disturbances in the metabolism due to presence of toxic principles like karanjin, phytate, trypsin inhibitor and tannins. And there was no improvement in body weight gain in karanj cake fed groups with supplementation of enzymes/ liver tonic suggesting that liver function and phytate content of karanj may not be limiting factors to hamper the birds performance (Raju *et al.,* 2010). The reports of Panda *et al.* (2006) in broiler chicken with karanj cake diet (6%) were in agreement with the present findings. Similar observations of poor weight gain were reported by feeding of either karanj cake in broiler by Panda *et al.* (2008), Raju *et al.* (2010) and Reddy *et al.* (2011).

**Table 2. Effect of dietary inclusion of detoxified *Karanj* cake with enzyme on performance of broiler chicken**

| Treatments ratio | Enzymes/ Liver Tonic in diet | Body weight gain (g) | Feed intake (g) | Feed conversion |
|---|---|---|---|---|
| $T_1$ - Control | - | 1961 [ab] | 3076 [ab] | 1.568 [de] |
| $T_2$ - Control | Protease (4000 U/kg) | 1972 [ab] | 3035 [abcd] | 1.539 [e] |
| $T_3$ - Control | Phytase (400 U/kg) | 2052 [a] | 3200 [a] | 1.560 [e] |
| $T_4$ - Control | Liver Tonic (0.1%) | 2024 [a] | 3207 [a] | 1.585 [cde] |
| $T_5$ - SKC (6%) | - | 1723 [d] | 2876 [d] | 1.669 [ab] |
| $T_6$ - SKC (6%) | Protease (4000 U/kg) | 1726 [d] | 2893 [cd] | 1.679 [ab] |
| $T_7$ - SKC (6%) | Phytase (400 U/kg) | 1762 [cd] | 3000 [bcd] | 1.702 [a] |
| $T_8$ - SKC (6%) | Liver Tonic (0.1%) | 1840 [cd] | 3012 [bcd] | 1.639 [abc] |
| $T_9$ - IPA treated SKC (6%) | - | 1875 [bc] | 3041 [abcd] | 1.623 [bcd] |
| $T_{10}$ - IPA treated SKC (6%) | Protease (4000 U/kg) | 1820 [cd] | 3033 [abcd] | 1.668 [ab] |
| $T_{11}$ - IPA treated SKC (6%) | Phytase (400 U/kg) | 1862 [bc] | 3062 [abc] | 1.647 [ab] |
| $T_{12}$ - IPA treated SKC (6%) | Liver Tonic (0.1%) | 1839 [cd] | 3099 [ab] | 1.688 [ab] |
| | N | 6 | 6 | 6 |
| | P value | 0.001 | 0.001 | 0.001 |
| | SEM | 15.90 | 18.43 | 0.008 |

Means bearing at least one common superscript in a column do not differ significantly (P<0.05)
SKC – Solvent extracted karanj cake; IPA – Isopropyl alcohol

**Feed consumption**

The feed consumption did not vary significantly among groups during the entire experimental period (Table 2). However, the total feed intake was lower in 6% SKC based diet with or without enzymes and remaining diets were found to be comparable among all the dietary groups. The supplementation of protease, phytase and liver tonic had no added advantage on feed intake when diet was incorporated with IPA treated SKC and SKC at 6% level which might be due to seasonal or unknown factors. Decrease in feed consumption recorded with karanj cake is in accordance with the findings of Panda *et al*. (2006) and Reddy *et al*. (2011). The reduction in feed consumption might be attributed to the bitter taste and pungent smell of karanj cake and interference of karanjin in the metabolism (Srivastava *et al*., 1990).

**Feed conversion ratio**

The dietary incorporation of IPA treated SKC and SKC at 6% level in the diet resulted in poor efficiency of feed utilization as compared to that of control diet except IPA treated SKC 6% group (Table 2). Supplementation of protease, phytase or liver tonic to this diet did not overcome the adverse effect during this entire experimental period. The poor FCR in karanj groups might be due to the toxic effects of karanj cake. These findings were in accordance with Reddy (2009) with 10% karanj cake inclusion, Panda *et al*. (2006) with 6% karanj cake inclusion in broiler chicken.

**Nutrient retention or digestibility**

The digestibility of DM and CP were significantly (P<0.05) lower in SKC and IPA treated SKC at 6% based diet compared to the control diet (Table 2). However, the digestibility of total ash increased significantly (P<0.05) with supplementation of protease, phytase or liver tonic compared to those fed the control diet, The percent retention of EE was similar among all the dietary groups (Table 3). The present study findings are in line with the observations of Kanwar *et al*. (1987) and Panda *et al*. (2004), who did not observe any difference in the retention of nutrients in broiler chicken. Hauge *et al*. (1996) and Srivastava *et al*. (1990) with 6 % de-oiled karanj cake reported significant reduction in nitrogen retention with in broiler chicks.

**Table 3. Effect of dietary inclusion of detoxified *Karanj* cake with enzyme on nutrient digestibility retention (%) of broilers**

| Treatments | Enzymes/ Liver Tonic in diet | Dry matter | Crude protein | Ether extract | Total ash |
|---|---|---|---|---|---|
| $T_1$ - Control | - | 77.67 [a] | 77.68 [a] | 86.70 | 20.83 [e] |
| $T_2$ - Control | Protease (4000 U/kg) | 77.80 [a] | 75.21 [a] | 86.88 | 29.48 [bcd] |
| $T_3$ - Control | Phytase (400 U/kg) | 74.95 [ab] | 66.91 [bc] | 82.11 | 28.28 [bcd] |
| $T_4$ - Control | Liver Tonic (0.1%) | 77.83 [a] | 73.57 [ab] | 87.73 | 35.01 [ab] |
| $T_5$ - SKC (6%) | - | 70.18 [c] | 62.24 [c] | 85.51 | 24.79 [de] |
| $T_6$ - SKC (6%) | Protease (4000 U/kg) | 70.13 [c] | 67.00 [bc] | 85.57 | 36.60 [a] |
| $T_7$ - SKC (6%) | Phytase (400 U/kg) | 71.23 [bc] | 61.17 [c] | 86.44 | 29.22 [bcd] |
| $T_8$ - SKC (6%) | Liver Tonic (0.1%) | 70.44 [c] | 62.46 [c] | 85.29 | 29.84 [abcd] |
| $T_9$ - IPA treated SKC (6%) | - | 70.76b [c] | 67.77 [bc] | 85.74 | 25.35 [cde] |
| $T_{10}$ - IPA treated SKC (6%) | Protease (4000 U/kg) | 68.68 [c] | 63.55 [c] | 84.63 | 32.31 [abc] |
| $T_{11}$ - IPA treated SKC (6%) | Phytase (400 U/kg) | 70.45 [abc] | 63.18 [c] | 84.44 | 30.27 [abcd] |
| $T_{12}$ - IPA treated SKC (6%) | Liver Tonic (0.1%) | 71.03 [bc] | 65.68 [c] | 84.38 | 29.09 [bcd] |
| N | | 3 | 3 | 3 | 3 |
| P value | | 0.01 | 0.01 | 0.228 | 0.002 |
| SEM | | 0.64 | 1.03 | 0.38 | 0.87 |

**Table 4. Cost of feeding of broilers, returns over feed cost and the difference of returns on *Karanj* diets over control diet during 0–42 days of age**

| Treatments | Enzymes/ Liver Tonic in diet | Cum. Body weight (kg) | Cum. Feed Cons. (kg) | Cum. Feeding cost (Rs.) | Sale amount* (Rs.) | Returns over feed cost (Rs. /bird) | Gain over control (Rs. /bird) |
|---|---|---|---|---|---|---|---|
| $T_1$ - Control | - | 2.006 | 3.080 | 58.99 | 104.3 | 45.32 | - |
| $T_2$ - Control | Protease (4000 U/kg) | 2.018 | 3.040 | 60.17 | 104.9 | 44.77 | -0.557 |
| $T_3$ - Control | Phytase (400 U/kg) | 2.097 | 3.200 | 63.53 | 109.0 | 45.52 | -0.194 |
| $T_4$ - Control | Liver Tonic (0.1%) | 2.069 | 3.210 | 62.02 | 107.6 | 45.57 | -0.247 |
| $T_5$ - SKC (6%) | - | 1.767 | 2.880 | 56.22 | 91.88 | 35.66 | -9.659 |
| $T_6$ - SKC (6%) | Protease (4000 U/kg) | 1.77 | 2.890 | 58.64 | 92.04 | 33.40 | -11.918 |
| $T_7$ - SKC (6%) | Phytase (400 U/kg) | 1.806 | 2.990 | 60.99 | 93.91 | 32.92 | -12.399 |
| $T_8$ - SKC (6%) | Liver Tonic (0.1%) | 1.886 | 3.010 | 59.47 | 98.07 | 38.61 | -6.7145 |
| $T_9$ - IPA treated SKC (6%) | - | 1.919 | 3.050 | 59.55 | 99.79 | 40.24 | -5.084 |
| $T_{10}$ - IPA treated SKC (6%) | Protease (4000 U/kg) | 1.865 | 3.040 | 61.43 | 96.98 | 35.55 | -9.775 |
| $T_{11}$ - IPA treated SKC (6%) | Phytase (400 U/kg) | 1.907 | 3.060 | 62.15 | 99.16 | 37.01 | -8.307 |
| $T_{12}$ - IPA treated SKC (6%) | Liver Tonic (0.1%) | 1.883 | 3.010 | 61.32 | 97.92 | 36.60 | -8.725 |

* The sale price of broilers was taken as Rs. 52/- per kg live weight

**Economics**

The returns over feed cost per kg weight gain and gain over control diet was higher in broilers fed the control diet compared to 6% SKC based diets fed groups (Table 4). Supplementation of additives, in general, enhanced the cost of feeding. From the results of the present study, it could be concluded that, IPA detoxification marginally enhanced nutritive feeding value of SKC for broiler chicken during 0 to 6 weeks of age. Supplementation of protease (4000 U/kg), phytase (400 U/kg) or liver tonic (0.1%) did not have any additional advantage on the performance of broiler chickens. Panda, (2004) reported that the poorer feed conversion and lowered weight gain in the birds fed diets incorporated with either processed or unprocessed karanj cake at 50% replacement level lead to higher unit cost of production in terms of both weight gain and edible meat.

**Mortality**

The mortality was within the standard limits and no specific trend could be noticed with regard to cause of death.

## CONCLUSION

The supplementation of protease (4000 U/kg), phytase (400 U/kg) or liver tonic (0.1%) in the SKC and IPA treated SKC were in the diet not improved the body weight gain, feed consumption, feed efficiency and nutrient retention of broilers. The returns over feed cost per kg weight gain and gain over control diet was higher in broilers fed the control diet compared to 6% karanj based diets. Finally, it can be concluded that supplementation of enzymes / liver tonic could not alleviate the toxic effects of SKC or IPA treated SKC at 6% level in the diet.

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# INCIDENCE OF CHILLI LEAF CURL COMPLEX DISEASE IN MAJOR CHILLI GROWING AREAS OF TELANGANA

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Chilli (*Capsicum annuum* L.) is one of the most valued cash crops of India. It is a common and widely cultivated spices crop almost all over the world. The chilli fruits are small in size and known for their sharp acidic flavour, pungency and colour. The major chilli producing states in India are Andhra Pradesh, Telangana, Tamil Nadu, Karnataka and Madhya Pradesh. In 2019-20, Telangana occupied second position in chilli in area, production and productivity *i.e.,* 2.98 lakh acres, production 3.06 lakh metric tonnes and productivity 1545 Kg per acre respectively. The major chilli growing districts are Khammam, Mahabubabad, Gadwal, Suryapet and Warangal (Rural) in Telangana. During 2020-21, 1.91 lakh acres was covered under chilli crop (Chilli Outlook, 2020).

Chilli is predisposed to multitude of viral, fungal, bacterial, nematode and phytoplasma diseases. Viruses are known to incite wide range of symptoms like mosaic, ring spot, curling, yellowing etc. Among them, chilli leaf curl is ubiquitous and infect entire plants in the field with variable symptoms such as leaf curling, puckering and reduced size of leaves, closely set internodes and dwarfing of plants (Zehra *et al.,* 2019). These symptoms produce witch broom appearance and affect fruit setting (either failure or small deformed fruit formation), Talukdar *et al.*, 2015. In tropical and subtropical parts of India, leaf curl is a major constraint to chilli and causes yield losses up to 80 per cent (Dhanraj *et al.*, 1968; Chattopadhyay *et al.,* 2008).

A roving survey was conducted during *Rabi* 2019-20 and *Rabi* 2020-21 in major chilli growing districts of Telangana to assess the status of leaf curl viral complex. Infected fields were identified based on external symptoms *i.e.,* curling of leaves, mosaic, yellowing, stunted growth, mosaic mottling, leaf rolling *etc.* Based on the symptoms observed, percent disease incidence was estimated. During survey, five micro areas with an area of 1m$^2$ in each field were observed randomly duly covering both healthy and infected plants to assess the incidence of chilli leaf curl. At every micro area, the total number of plants and number of disease affected plants were recorded. The per cent disease incidence of each chilli field was calculated as per the formula given below and further mean per cent disease incidence of each village was also calculated.

$$\text{Per cent disease incidence} = \frac{\text{Total number of infected plants}}{\text{Total number of plants observed}} \times 100$$

The details like variety, fertilizer dosages, pesticide spray schedule, pesticides used, management practices followed were also recorded.

A field survey was conducted in *Rabi* 2019-20 and *Rabi* 2020-21 in six districts namely Warangal, Mahbubabad, Mulugu, Jayashankar Bhupalpally, Nagarkurnool and Khammam which are major chilli growing areas of Telangana (Table 1). A total of 280 fields were surveyed for incidence of chilli leaf curl complex. The results of survey revealed that most of the fields were found more than one viral infected symptoms. The virus infected leaf sample were collected and visually diagnosed as leaf curl, mosaic mottle, puckering, yellowing, leaf rolling and distortion mosaic as per the standard procedure given by Paul and Fernando, (1939).

The results from all the districts (Table 1) revealed that the average disease intensity was comparatively more in *Rabi* 2019 than *Rabi* 2020, especially in Khammam district which recorded 41.59 per cent in *Rabi* 2019 than in *Rabi* 2020 (29.04 %). Similarly in Warangal district the disease incidence was

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38.8 per cent in *Rabi* 2019 while it was recorded as 31.18 per cent during *Rabi* 2020 followed by Mahabubabad district which recorded 26.79 per cent in *Rabi* 2019 and 21.88 per cent in *Rabi* 2020. However, Jayashankar Bhupalpally, Mulugu districts recorded almost similar incidence during both the seasons of survey. Nagarkurnool district recorded the least disease incidence with 20.21 per cent during *Rabi* 2019 and 17.17 per cent in *Rabi* 2020.

During *Rabi* 2019, it was observed that maximum disease incidence was recorded in Duggondi mandal (57.29%) of Warangal district, followed by Wyra mandal (55.20%) of Khammam district, while least incidence was recorded in Chalwai mandal (11.11%) of Mulugu district.

In *Rabi* 2020, maximum incidence was observed in Yellandu mandal (51.44%) of Khammam district followed by Chennaram mandal (48.73%) of Warangal district, while least incidence was recorded in Chintalpalle (8.94%) of Mahabubabad district. The data indicated that disease incidence varied from one field to the other, in each mandal and district surveyed in both the seasons (Table 1). These variations in incidence can be directly correlated to the popular variety grown, weather conditions, and vector incidence *etc.*

A study conducted by Chaubey and Mishra (2017) in eastern parts of Uttar Pradesh revealed that the occurrence of leaf curl in chilli ranged from 20-55 per cent. Bhagavathi Devi *et. al.,* 2019 also reported that leaf curl incidence in Guntur district of Andhra Pradesh was ranging from 30-60 per cent, Narpali mandal of Anantapur district recorded highest incidence of 90 per cent. N.G. Padu mandal of Prakasam district recorded least incidence of 20 per cent.

During the survey, different types of viral symptoms were observed in all the districts. The major symptoms of chilli leaf curl complex are curling of leaf

**Table 1. Survey for chilli leaf curl disease incidence during *Rabi* 2019 - 20 and *Rabi* 2020 - 21 in chilli growing districts of Telangana**

| S.No | District | Mandal | No. of fields surveyed | Percent disease incidence 2019-20 | Percent disease incidence 2020-21 |
|---|---|---|---|---|---|
| 1 | Warangal | Duggondi | 5 | 57.29 | 46.93 |
| | | Mysampally | 3 | 45.23 | 35.72 |
| | | Wardhannapet | 6 | 51.23 | 23.65 |
| | | Nallabelli | 5 | 45.6 | 35.2 |
| | | Togarampalli | 7 | 32.50 | 22.93 |
| | | Yellanda | 7 | 25.35 | 16.36 |
| | | Chennaram | 5 | 35.60 | **48.73** |
| | | Sangem | 10 | 32.90 | 36.96 |
| | | Machapur | 5 | 26.36 | 22.39 |
| | | Neredpalle | 4 | 25.96 | 22.96 |
| | | **Average incidence** | | 38.80 | 31.18 |
| | | **SEm±** | | **3.95** | **3.52** |
| 2 | Khammam | Bonakal | 9 | 35.69 | 32.63 |
| | | Kamepally | 7 | 42.69 | 36.23 |
| | | Kusumanchi | 7 | 35.73 | 25.89 |
| | | Mudigonda | 7 | 32.69 | 14.23 |
| | | Madhira | 5 | 35.63 | 17.93 |
| | | Yellandu | 5 | 45.63 | **51.44** |
| | | Chintakani | 7 | 46.36 | 35.23 |
| | | Wyra | 5 | **55.20** | 36.96 |
| | | Enkoor | 5 | 43.69 | 19.26 |

**Table 1 (Cont.)**

| S.No | District | Mandal | No. of fields surveyed | Percent disease incidence 2019-20 | Percent disease incidence 2020-21 |
|---|---|---|---|---|---|
| | | Kalluru | 6 | 42.60 | 20.63 |
| | | **Average incidence** | | 41.59 | 29.04 |
| | | **SEm±** | | **2.14** | **3.63** |
| 3 | Mahabubabad | Kuravi | 7 | 36.93 | 23.63 |
| | | Kesamudram | 6 | **44.07** | 35.63 |
| | | Mariped | 8 | 26.32 | 24.65 |
| | | Gangaram | 5 | 24.96 | **37.07** |
| | | Dornakal | 6 | 35.69 | 23.65 |
| | | Danthalapalle | 9 | 23.45 | 15.69 |
| | | Gudur | 5 | 16.98 | 18.69 |
| | | Kothaguda | 6 | 17.93 | 15.23 |
| | | Chintalpalle | 8 | 12.63 | 8.94 |
| | | Thorrur | 5 | 28.96 | 15.69 |
| | | **Average incidence** | | 26.79 | 21.88 |
| | | **SEm±** | | **3.11** | **2.85** |
| 4 | Jayashanker Bhupalpally | Amudalapalli | 5 | 25.63 | 22.53 |
| | | Bavusinghpalli | 3 | 14.56 | 19.65 |
| | | Deekshakunta | 5 | 18.65 | 14.57 |
| | | Dudekulapalli | 3 | 25.63 | 20.01 |
| | | Kamalapur | 3 | 24.59 | 16.57 |
| | | Kothapalli | 5 | 22.65 | 29.07 |
| | | **Average incidence** | | 21.95 | 20.4 |
| | | **SEm±** | | **1.82** | **2.07** |
| 5 | Nagarkurnool | Yendabatla | 5 | 15.32 | 17.87 |
| | | Nallavelli | 6 | 16.61 | 15.34 |
| | | Gummakonda | 5 | 26.65 | 16.87 |
| | | Auraspalle | 4 | 29.39 | 22.53 |
| | | Chandubatla | 3 | 18.93 | 17.63 |
| | | Narsapalle | 3 | 14.41 | 12.79 |
| | | **Average incidence** | | 20.21 | 17.17 |
| | | **SEm±** | | **2.56** | **1.31** |
| 6 | Mulugu | Chalapaka | 3 | 22.06 | 20.01 |
| | | Bussapur | 5 | 32.05 | 15.93 |
| | | Govindaraopet | 3 | 21.11 | 20.17 |
| | | Karlapally | 3 | 16.23 | 26.54 |
| | | Ghousepalli | 3 | 12.56 | 15.89 |
| | | Chalwai | 3 | 11.11 | 15.63 |
| | | **Average incidence** | | 19.18 | 19.02 |
| | | **SEm±** | | **3.13** | **1.72** |

margin, reduction in leaf size, vein clearing accompanied by puckering, thickening and swelling of the veins. These symptoms on chilli plants were recorded and grouped. Then the symptoms were identified and severity was estimated.

The major viral symptoms observed during survey were leaf rolling (Fig.1), mosaic mottling (Fig. 2) leaf curl (Fig. 3), vein clearing (Fig. 4), mosaic, and necrotic lesions. The present study showed that severe incidence of leaf curl was observed in all the 6 districts.

Menike and De Costa (2017) reported that there is variation in field symptoms in samples collected from parts of Sri Lanka and the major field symptoms observed on the plants infected with leaf curl were boat shaped puckering, stunted growth, leaf curling, yellowing and crinkling.

The data revealed that in Warangal district, leaf curl and mosaic mottling were more prominent when compared to vein clearing, leaf rolling, necrotic lesions (Table 2). Symptoms of leaf curl, leaf rolling and mosaic were severe in Khammam district. In Mahabubabad district leaf curl symptom was predominant, whereas in Nagarkurnool and Mulugu districts leaf curl symptom was severe. Bhagavathi Devi *et al.,* 2019 reported that Teja, Guntur mirchi, Local cultivars were prone to severe incidence of leaf curl in major chilli growing parts of Andhra Pradesh.

**Symptoms of leaf curl disease complex**

**Figure 1. Leaf rolling**

**Figure 2. Mosaic mottling**

**Figure 3. Leaf curling**

**Figure 4. Interveinal chlorosis**

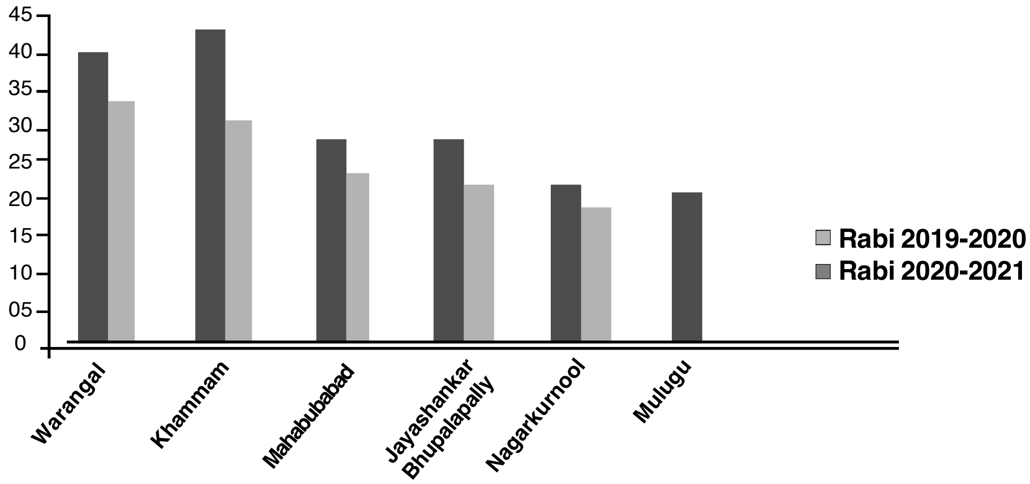


**Figure 5. PDI observed during survey in different districts**

**Table 2. Typical viral symptoms observed in different districts during survey**

| S.No | District | Symptoms observed | | |
|---|---|---|---|---|
| | | Mild incidence | Moderate incidence | Severe incidence |
| 1 | Warangal | VC, NL | LR, Mosaic | LC, MM |
| 2 | Khammam | VC,MM | NL | LC, LR, Mosaic |
| 3 | Mahabubabad | VC, Mosaic | LR,MM | LC |
| 4 | Jayashankar Bhupalpally | Mosaic | LC,MM | - |
| 5 | Nagarkurnool | Mosaic | MM,LC | LC,LR |
| 6 | Mulugu | MM | NL | LC |

* VC- Vein clearing, NL- Necrotic lesions, LR- Leaf rolling, MM- Mosaic mottling, LC- Leaf curl

**Table 3. Reaction of different cultivars/hybrids for disease severity in different districts of Telangana state**

| S.No | District | Symptoms observed | | |
|---|---|---|---|---|
| | | Mild incidence | Moderate incidence | Severe incidence |
| 1 | Warangal | Tejaswini, Yashaswini,G4 | Raasi gold, Guntur hot | Teja, Local |
| 2 | Khammam | Tejaswini, Jwala | Guntur hot | Teja, Kiran |
| 3 | Mahabubabad | - | Guntur hot | Local, Teja, |
| 4 | Jayashankar Bhupalpally | Tomato mirchi | Guntur hot | Local, Guntur hot |
| 5 | Nagarkurnool | Tulsi | Kiran, Teja, Aparna | - |
| 6 | Mulugu | Tomato mirchi | Pioneer | Local, Guntur hot |

Cultivars play a major role in disease incidence. The present study revealed that in Warangal and Mahabubabad districts Teja, Local cultivars were showing severe incidence, in Khammam Teja and Kiran varieties were more vulnerable. However, in Jayashankar Bhupalpally and Mulugu districts Local cultivar and Guntur hot recorded severe incidence (Table 3).

In almost all the cultivars examined in different districts, whitefly infestation was noticed during the flag end of the crop growth or termination stage *i.e.,* during January and February months. With regard to whitefly population, presence of only *Bemisia tabaci* in all the districts was recorded. The population constituted between 4-20 whiteflies 3 $P^{-1}$ (2019-20) and 5-15 whiteflies 3 $P^{-1}$ (2020-21). During both the years of

**Table 4. Occurrence and distribution of whitefly population in different districts under survey during *Rabi* 2019 & 2020**

| District name | Whitefly population | |
|---|---|---|
| | ***Rabi* 2019** | ***Rabi* 2020** |
| Warangal | 6.50 (2.00-19.00) | 8.5 (1.00-19.00) |
| Khammam | 5.75 (2.00-19.00) | 6.53 (1.00-19.00) |
| Mahabubabad | 5.26 (4.00-17.00) | 7.25 (2.00-17.00) |
| Mulugu | 1.25 (0.00-13.00) | 1.55 (0.00-12.00) |
| Nagarkurnool | 1.35 (0.00-12.00) | 2.55 (0.00-11.00) |
| Jayashankar Bhupalpally | 5.10 (2.00-14.00) | 5.75 (3.00-18.00) |
| **Mean** | 4.2 | 5.15 |

*Mean of 18 leaves per plant

study whitefly infestation was highest in Warangal (6.53 whiteflies 3 $P^{-1}$; 8.50 whiteflies 3 $P^{-l}$) followed by Khammam (5.75; 6.35), Mahabubabad (5.26; 7.25), Jayashankar Bhupalpally (5.10; 5.75), Nagarkurnool (1.35; 2.55) and Mulugu (1.25; 1.55) (Table 4). It has been observed that there was not much difference in its occurrence in rainfed - direct sown and irrigated - transplanted crop grown in these districts surveyed.

Whitefly was able to transmit ChiLCV from field samples to 50–100% of chilli test plants, which produced typical disease symptoms (Senanayake *et al.* 2007). An overall survey revealed that chilli leaf curl virus was found in all surveyed fields in continuous growing period. It might be attributed to growing of susceptible local cultivars, erratic spray schedule, incessant spraying, high dosages of pesticides, weed population prevailing in the districts as for multiplication of vector and spread of virus (Abhijit and Chatterjee, 2018).

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# INTERACTIVE EFFECTS OF WATER AND NITROGEN STRESS ON BIOMASS ACCUMULATION, NITROGEN UPTAKE AND SEED YIELD OF MAIZE

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Maize is a multi-faceted crop used as food, feed and industrial crop globally. It is grown throughout the world, with the United States, China, and Brazil being the top three maize producing countries in the world, producing approximately 563 of the 717 million tons/year (Ranum *et al.,* 2019). Water and nitrogen are the most important factors which play a major role in better growth and yield of maize (Hammad *et al.,* 2011). Maize crop growth is affected by different stresses *viz.,* deficit irrigation, pest, weed, nutrients, etc., which reduce the productivity. Water stress occurring at different crop developmental stages could potentially limit biomass accumulation and consequently reduce grain yield of the maize crop. The interactive effects of water and nitrogen shows an impact on morphological, physiological and yield attributes of maize. Ramachandiran and Pazhanivelan, (2015) stated that, owing to the increased frequency of irrigation along with a higher dose of nitrogen application leading to increased nutrient uptake, higher photosynthetic rate leading to higher plant height, LAI and dry matter production. Whereas, when maize grown under conditions of limited water supply requires less nitrogen to achieve the maximum grain yield than that required with well water supply (Moser *et al*., 2006). Optimization of nitrogen dose based on availability of soil moisture and crop response is need of hour. Hence this investigation was designed to study the yield response of maize crop under differential water and nitrogen levels to optimize the nitrogen use based on availability of water for irrigation in maize crop.

The experiment was conducted in the Research farm of Agro-Climatic Research Centre, Agricultural Research Institute, PJTSAU, Rajendranagar, Hyderabad. The soil is sandy loam in texture and neutral in reaction with a pH of 7.45. The soil was low in organic carbon (0.26%), medium nitrogen (149 kg $ha^{-1}$), phosphorus (35.0 kg $ha^{-1}$) and potassium (394 kg $ha^{-1}$). The experiment was laid out in split-plot design replicated thrice. The treatments comprised of three irrigation scheduling *viz.,* 20%, 40% and 60%. Depletion of Available Soil Moisture (DASM) assigned to main plots and three nitrogen levels *viz.,* 120, 180 and 240 kg N $ha^{-1}$ assigned to sub plots. The field was laid out in ridges and furrows at 60 cm apart. The plant to plant spacing within the row was 20 cm. All the treatments were uniformly irrigated initially up to 15 days after sowing to ensure the better establishment of the crop. The bio mass accumulation was recorded stage wise. Whereas grain yield, stover yield and harvest index were estimated after harvesting the crop.

The influence of irrigation scheduling, nitrogen levels and their interaction on biomass accumulation was presented in Table 1. At silking stage, the crop irrigation scheduled at 20 % DASM ($I_1$) accumulated more biomass of 129.7 g $plant^{-1}$ and it was decreased significantly from 121.2 g $plant^{-1}$ to 94.4 g $plant^{-1}$ with increasing interval between two successive irrigations scheduled at 40 % DASM ($I_2$) and 60 % DASM ($I_3$), respectively. The maximum biomass accumulation with frequently irrigated treatment (20% DASM) might be due to the optimum soil moisture conditions prevailed in rhizosphere throughout the crop growth period. These results are in line with the findings of Dong *et al.* (2020), Soujanya *et al.* (2020). At silking stage, a significant increase in biomass accumulation from 184.7 g $plant^{1}$ to 211.9 g $plant^{-1}$ was observed with increasing nitrogen dose from 120 kg N $ha^{-1}$ ($N_1$) to 180 kg N $ha^{-1}$ ($N_2$), respectively. However, further increasing

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**Table 1. Bio mass accumulation (g $plant^{-1}$) of Maize at different growth stages as influenced by irrigation scheduling and nitrogen levels**

| Crop stage | 6th Leaf stage | | | | Silking stage | | | | Dough stage | | | | Physiological maturity stage | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **N1** | **N2** | **N3** | **Mean** | **N1** | **N2** | **N3** | **Mean** | **N1** | **N2** | **N3** | **Mean** | **N1** | **N2** | **N3** | **Mean** |
| $I_1$ | 4.7 | 6.3 | 5.9 | 5.7 | 105.1 | 135.7 | 148.4 | 129.7 | 191.6 | 230.5 | 244.2 | 222.1 | 193.3 | 228.5 | 252.0 | 224.6 |
| $I_2$ | 7.4 | 6.5 | 6.6 | 6.9 | 115.6 | 123.1 | 124.8 | 121.2 | 198.6 | 217.1 | 224.2 | 213.3 | 204.5 | 215.4 | 221.5 | 213.8 |
| $I_3$ | 5.6 | 5.5 | 5.7 | 5.6 | 78.8 | 102.0 | 102.4 | 94.4 | 163.9 | 187.9 | 188.1 | 180.0 | 170.3 | 188.5 | 192.4 | 183.7 |
| **Mean** | 5.9 | 6.1 | 6.1 | 6.0 | 99.8 | 120.3 | 125.2 | 115.1 | 184.7 | 211.9 | 218.8 | 205.1 | 189.4 | 210.8 | 222.0 | 207.4 |
| | S.Em± | | CD (p=0.05) | | S.Em± | | CD (p=0.05) | | S.Em± | | CD (p=0.05) | | S.Em± | | CD (p=0.05) | |
| Main (I) | 0.2 | | NS | | 1.4 | | 5.8 | | 2.1 | | 8.3 | | 1.5 | | 6.0 | |
| Sub (N) | 0.3 | | NS | | 2.2 | | 6.8 | | 2.1 | | 6.5 | | 3.1 | | 9.5 | |
| Sub (N) at same main (I) | 0.6 | | NS | | 3.8 | | 11.9 | | 3.6 | | 11.2 | | 15.3 | | 16.5 | |
| Main (I) at same or different sub (N) | 0.5 | | NS | | 3.4 | | 11.2 | | 3.6 | | 12.2 | | 4.6 | | 14.7 | |

**Note :** $I_1$ : 20 % DASM; $I_2$: 40 % DASM; $I_3$: 60 % DASM
$N_1$ : 120 kg N $ha^{-1}$; $N_2$: 180 kg N $ha^{-1}$; $N_3$: 240 kg N $ha^{-1}$
DASM - Depletion of Available Soil Moisture

nitrogen dose to 240 kg N $ha^{-1}$ ($N_3$), did not contribute any significant increment in biomass accumulation. The reduction in biomass accumulation at lower doses of nitrogen could be due to deficiency of N which acts as the building block of protein, a constituent of chlorophyll, essential for carbohydrate formation and its deficiency finally led to reduction in dry matter accumulation. The reduction in biomass accumulation with decreasing nitrogen levels was also reported by several researchers (Begam *et al*., 2018, Joshi *et al.,* 2013). Among the different treatment combinations, irrigation scheduling at 20 % DASM in conjunction with 240 kg N $ha^{-1}$ ($I_1N_3$) recorded significantly higher biomass of 148.4 g $plant^{-1}$, 244.2 g $plant^{-1}$ and 252.0 g $plant^{-1}$ over other treatment combinations at silking, dough and physiological maturity stages, respectively. These results are in line with the findings of Krishnaprabu, (2018) who also reported that, a positive response in terms of biomass accumulation was observed up to 160 kg N $ha^{-1}$ and further increase in nitrogen dose from 200 kg to 300 kg N $ha^{-1}$, the biomass was decreased when crop irrigation scheduled at 75% DASM or grown under rainfed situation as compared to irrigation scheduling at 25% DASM.

The effect of irrigation scheduling, nitrogen levels and their interactions on grain yield was summarized and presented in Table 2. The crop irrigation scheduled at 20 % DASM ($I_1$) recorded higher grain yield of 5781 kg $ha^{-1}$. However, it was comparable with $I_2$ (40% DASM) treatment (5593 kg $ha^{-1}$) and significantly superior over $I_3$ (60% DASM) treatment (3327 kg $ha^{-1}$). Under optimal soil moisture conditions ($I_1$ and $I_2$), the maize crop could able to synthesize and accumulate more photosynthates resulted in maximum biomass accumulation. The accumulated biomass in different plant parts (leaf and stem) were translocated successfully to sink (grain) under optimal transpirational pool maintained by the crop throughout the growth period. These results are in accordance with the findings of Kumari *et al*. (2017) who reported that, irrigation scheduling at 25% DASM (4.6 t/ha) resulted in 26.7% and 15.4%, higher grain yield when compared to irrigation scheduling at 75% DASM and raising the crop under rained situation, respectively.

A significant increase in grain yield from 3904 kg $ha^{-1}$ to 5227 kg $ha^{-1}$ was observed with increasing nitrogen dose from 120 kg N $ha^{-1}$ ($N_1$) to 180 kg N $ha^{-1}$ ($N_2$), respectively. However, further increasing nitrogen dose to 240 kg N $ha^{-1}$ ($N_3$), did not contribute any significant increment. The interaction effect of irrigation scheduling and nitrogen levels on grain yield of maize was significant. Among the different treatment combinations, 20% DASM in conjunction with 240 kg N $ha^{-1}$ ($I_1N_3$) recorded highest grain yield of (6979 kg $ha^{-1}$). However, it was on par with $I_1N_2$ (6620 kg $ha^{-1}$), $I_2N_3$ (6267 kg $ha^{-1}$) and $I_2N_2$ (5714 kg $ha^{-1}$) and significantly superior over rest of the treatment combinations. The increment in soil water availability increases N absorption, contributing to the linear increase of biomass in maize plants (Wang *et al*., 2017) and thus, the water availability amplifies the grain yield through a better use of N whereas low moisture tress restricts the N availability and reduce the yield of maize crop (Paolo & Rinaldi, 2008).

The effect of irrigation scheduling on stover yield of maize was significant (Table 2). The crop irrigation scheduled at 20 % DASM ($I_1$) recorded highest stover yield of 9296 kg $ha^{-1}$. However, it was comparable with $I_2$ (40% DASM) treatment (8439 kg $ha^{-1}$) and significantly superior over $I_3$ (60% DASM) treatment (5898 kg $ha^{-1}$). These results were in agreement with the findings of Awasthy *et al.,* 2015 who reported that the favourable effect of moisture is through its effect on initiating vigorous growth leading to relatively higher seed weight and consequently increased grain yield. The effect of nitrogen levels on stover yield of maize was found to be non- significant. Among the different treatment combinations, $I_1N_3$ recorded highest stover yield of 10587 kg $ha^{-1}$. However, it was on par with $I_1N_2$ (9490 kg $ha^{-1}$) and significantly superior over rest of the treatment combinations. The increase in stover yield might be due to combined effect of irrigation and nitrogen levels which increased the availability of nutrients. Similar results were obtained by Kumari *et al*. (2017). Higher doses of nitrogen are known to enhance vegetative growth of the plant. The higher vegetative growth at 240 kg/ha, but dis- proportionate diversion of dry matter from source to sink might have resulted in the higher stover yield and lower grain yield at higher N- application rates.

The effect of irrigation scheduling and nitrogen levels on Harvest index of maize was presented in Table 2. The influence of irrigation scheduling on harvest index was found to be non- significant. A significant difference in harvest index of maize was observed with respect to different levels of nitrogen. The crop

**Table 2. Grain yield, Stover yield and Harvest Index of Maize as influenced by irrigation scheduling and nitrogen levels**

| Yield Parameters | Grain Yield (kg ha$^{-1}$) | | | | Stover Yield (kg ha$^{-1}$) | | | | Harvest Index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | N1 | N2 | N3 | Mean | N1 | N2 | N3 | Mean | N1 | N2 | N3 | Mean |
| $I_1$ | 3744 | 6620 | 6979 | 5781 | 7810 | 9490 | 10587 | 9296 | 0.29 | 0.41 | 0.40 | 0.37 |
| $I_2$ | 4800 | 5714 | 6267 | 5593 | 8768 | 8342 | 8208 | 8439 | 0.35 | 0.40 | 0.43 | 0.40 |
| $I_3$ | 3168 | 3346 | 3466 | 3327 | 5926 | 5939 | 5828 | 5898 | 0.35 | 0.36 | 0.37 | 0.36 |
| Mean | 3904 | 5227 | 5571 | 4900 | 7501 | 7924 | 8208 | 7878 | 0.33 | 0.39 | 0.40 | 0.37 |

| | Grain S.Em± | Grain CD (p=0.05) | Stover S.Em± | Stover CD (p=0.05) | HI S.Em± | HI CD (p=0.05) |
|---|---|---|---|---|---|---|
| Main (I) | 256 | 1004 | 367 | 1441 | 0.01 | NS |
| Sub (N) | 186 | 572 | 221 | NS | 0.01 | 0.03 |
| Sub (N) at same main (I) | 322 | 991 | 383 | 1181 | 0.02 | NS |
| Main (I) at same or different sub (N) | 367 | 1281 | 482 | 1722 | 0.02 | NS |

**Note :** $I_1$ : 20 % DASM; $I_2$: 40 % DASM; $I_3$: 60 % DASM, $N_1$ : 120 kg N ha$^{-1}$; $N_2$: 180 kg N ha$^{-1}$; $N_3$: 240 kg N ha$^{-1}$, DASM - Depletion of Available Soil Moisture

**Table 3. Nitrogen uptake (kg ha$^{-1}$) of Maize at different growth stages as influenced by irrigation scheduling and nitrogen levels**

| Crop stage | 6th Leaf stage | | | | Silking stage | | | | Dough stage | | | | Physiological maturity stage | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | N1 | N2 | N3 | Mean | N1 | N2 | N3 | Mean | N1 | N2 | N3 | Mean | N1 | N2 | N3 | Mean |
| $I_1$ | 6.46 | 9.13 | 8.97 | 8.19 | 71.99 | 92.10 | 100.78 | 88.29 | 139.40 | 177.79 | 155.10 | 157.43 | 135.68 | 168.52 | 180.16 | 161.45 |
| $I_2$ | 8.29 | 9.84 | 9.92 | 9.35 | 73.00 | 75.98 | 77.51 | 75.50 | 131.81 | 156.99 | 156.33 | 148.37 | 130.80 | 144.06 | 156.29 | 143.72 |
| $I_3$ | 7.52 | 8.40 | 7.61 | 7.84 | 53.58 | 63.64 | 62.25 | 59.82 | 126.30 | 152.00 | 121.56 | 133.28 | 122.69 | 139.88 | 117.41 | 126.66 |
| **Mean** | 7.42 | 9.13 | 8.83 | 8.46 | 66.19 | 77.24 | 80.18 | 74.54 | 132.50 | 162.26 | 144.33 | 146.36 | 129.72 | 150.82 | 151.29 | 143.94 |

| | 6th Leaf S.Em± | 6th Leaf CD (p=0.05) | Silking S.Em± | Silking CD (p=0.05) | Dough S.Em± | Dough CD (p=0.05) | Phys. maturity S.Em± | Phys. maturity CD (p=0.05) |
|---|---|---|---|---|---|---|---|---|
| Main (I) | 0.45 9 | 1.801 | 3.724 | 3.724 | 3.897 | 15.302 | 7.082 | 27.809 |
| Sub (N) | 0.731 | 2.251 | 2.090 | 2.090 | 5.372 | 16.552 | 6.736 | 20.757 |
| Sub (N) at Same main (I) | 1.266 | 3.900 | 3.620 | 3.620 | 9.304 | 28.670 | 11.668 | 35.952 |
| Main (I) at same or different sub (N) | 1.131 | 3.641 | 4.754 | 4.754 | 8.538 | 27.812 | 11.871 | 40.149 |

**Note :** $I_1$ : 20 % DASM; $I_2$: 40 % DASM; $I_3$: 60 % DASM, $N_1$ : 120 kg N ha$^{-1}$; $N_2$: 180 kg N ha$^{-1}$; $N_3$: 240 kg N ha$^{-1}$, DASM - Depletion of Available Soil Moisture nurtured with 240 kg N $ha^{-1}$ (N3) recorded highest harvest index of 0.40 which was comparable with 180 kg N $ha^{-1}$ (0.39) and significantly superior over 120 kg N $ha^{-1}$ (0.33). The increase in harvest index with nitrogen dose was also reported by several researchers (Hammad *et al.*, 2011, Tafteh and Sepaskhah, 2012). The interaction effect of irrigation scheduling and nitrogen levels on harvest index was found to be not significant.

There was a significant difference in nitrogen uptake under irrigation scheduling at six leaf, silking, dough and physiological maturity stages of the crop (Table 3). The crop irrigation scheduled at 20 % DASM (I1) recorded a higher uptake of nitrogen at six leaf, silking, dough and physiological maturity stages, respectively. However, it was comparable with I2 (40% DASM) treatment at six leaf, silking, dough and physiological maturity stages, respectively. The least uptake of nitrogen was recorded in the crop irrigation scheduled at 60% DASM (I3). These results are in accordance with findings of Djaman *et al.* (2013) who also reported that higher irrigation level resulted in a significant increase in plant-nutrient uptake. A significant difference in uptake of nitrogen in maize was observed at silking and dough stages only. At silking stage, the crop nurtured with 180 kg N $ha^{-1}$ (N2) recorded more nitrogen uptake (80 kg N $ha^{-1}$). However, it was comparable with 240 kg N $ha^{-1}$ (77 kg N $ha^{-1}$) and significantly superior over 120 kg N $ha^{-1}$(74 kg N $ha^{-1}$). These results are line with Kumari *et al.* (2017) stated that, the uptake of N in grain increased significantly up to 160 kg N $ha^{-1}$ and further increase in N-rate up to 300 kg N $ha^{-1}$ decreased the N uptake. The combined effect of irrigation scheduling and nitrogen levels on accumulation of nitrogen in leaves at different phenophases was presented in table 3. Among the different treatment combinations, I1N3 recorded highest nitrogen uptake. However, it was on par with I1N2 and significantly superior over rest of the treatment combinations. These results are line with Soujanya *et al.* (2020) who opined that significant response in terms of the nitrogen uptake by plant was observed up to 180 kg N $ha^{-1}$. Under deficit soil moisture condition, 60% DASM the maximum nitrogen uptake by plant was recorded with low nitrogen dose of 90 kg N $ha^{-1}$ and nitrogen uptake was decreased with increasing nitrogen dose.

The inference of this investigation is that, interaction between water and nitrogen significantly influenced the growth, yield and nitrogen accumulation in above ground biomass. The crop irrigation scheduling at 40% depletion of available soil moisture in conjunction with 180 kg N $ha^{-1}$ can be recommended for optimum grain and stover yield of maize crop.

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# EXTENT AND INTENSITY OF RURAL INDEBTEDNESS IN WARANGAL (RURAL) DISTRICT OF TELANGANA STATE: INSIGHTS FROM A FIELD STUDY

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The rural sector plays an important role in the Telangana economy. Nearly two-thirds of the Telangana population lives in rural areas, whose primary occupation is agriculture and allied sectors. The rural sector however is facing serious challenges such as increasing agrarian distress, rural and urban migration, shrinking non-farm employment, etc. As a result, rural distress is becoming a great challenge for future Telangana. Poverty is perhaps a major cause of rural indebtedness. The low level of rural incomes, the uncertain and primitive farming of small landholdings, make it impossible to meet the needs required for their living. It is reported that about 70 percent of India's 90 million farmers spend more than they earn on average each month (Saha, 2017). Similarly, in Telangana state about 84 per cent of farm households spend more than their monthly income (NSSO, 2013). Often, rural people borrow to bridge this gap between meeting their farm and non-farm needs.

Despite impressive progress in agriculture in Telangana state, a farmer's crisis has emerged as a big challenge in recent past, due to increased indebtedness among rural households. One of the key reasons for the present rural distress is the increasing menace of rural indebtedness besides other reasons such as decreasing farm profitability, non-availability of non-farm employment sources, etc. Further increasing household expenditure is coupled with decreasing rural incomes, especially after the mid-90s, in view of the globalization and economic reforms being pursued in India since the mid-90s (Chand, 2017). As a result, household expenditure on education, health, and other social events has increased tremendously due to the privatization of this sector and the negligence of public education and health systems.

In the state of Telangana, about 31,144 farmers have committed suicides during the period 1995-2019 (NCRB, 1995-2019). The state's share in India's farmers suicides is still at large, i.e. 9 per cent. Among the undivided ten districts of Telangana state, Warangal was more prone to farmer's suicides which accounted for 18 per cent of total farmer's suicides in the state during the period 2014-19 (Rural Development Service Society, 2019.). Therefore, this study was undertaken in Warangal rural district with primary objective of analyzing the extent, intensity and composition of rural indebtedness and reasons for indebtedness among the sample rural households in the study area.

Two mandals, namely Khanapur and Rayaparthy, were selected for this study on the basis of the extent of area under paddy and cotton respectively. In Khanapur mandal, two predominately paddy-growing villages were selected. Similarly, in Rayaparthy mandal two major cotton-growing villages were selected. A total of four villages were selected for this study. From each village, 15 farm households were randomly selected in proportion to the presence of marginal, small, medium and large farmers. Accordingly, out of 60 sample farm households (@ 15 from each village), 30 marginal, 15 small, 9 medium and 6 large farm households were selected. In addition, 15 non-farm households were also selected randomly from each village to represent non-farm households in the study area. The primary data collected from the sample households is the main source of data for this study. A personal interview with the head of the sample households was adopted to administer the questionnaire. A simple tabular analysis and arithmetic measures were used to assess the extent, intensity, and composition of indebtedness among sample

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households. Garrett's ranking technique was employed for identifying the reasons for indebtedness of sample households.

The basic socio-economic profile of the selected sample households is presented in Table 1. It is observed that the average age of the heads of farm households is 45 years, which is slightly lower than the age of non-farm household heads. Nearly 42-45 per cent of farm households are illiterate, while the intensity of illiteracy was higher among non-farm households (Table1). Only 13 per cent of sample non farm households have a degree or above educational level. The average family size of farm rural households was nearly double to the average family size of non-farm rural households in this study area.

**Table 2. Frequency distribution of sample farm households by level of indebtedness**

| S.No | Range of indebtedness | No of farm households | No of farm households in debt (%) |
|---|---|---|---|
| 1 | >1,50,000 | 19 | 33 |
| 2 | 50,000-1,50,000 | 15 | 26 |
| 3 | <50,000 | 26 | 45 |

**Source:** Primary data collected from sample farm households
Highest outstanding debt of farm households - 4,00,000
Lowest outstanding debt of farm households - 0
(3 members)

As a whole, the highest outstanding dues of an indebted farmer was Rs. 4,00,000 and only three out of 60 sample households did not report any outstanding dues. Similarly, 77 per cent of sample nonfarm households have outstanding dues with less than Rs. 50,000, 35 per cent of them have outstanding dues in the range of Rs. 50,000 to 1,50,000 and 28 per cent have outstanding dues more than Rs. 1,50,000 (Table 3). The highest outstanding dues in case of non-farm household was noticed at Rs. 9,00,000.

**Table 1. Basic socio-economic profile of sample rural households**

| S.No | Particulars | Farm rural households | | | | | Non-farm rural households |
|---|---|---|---|---|---|---|---|
| | | Marginal | Small | Medium | Large | Average | |
| 1 | **Age (year)** | 47 | 42 | 44 | 41 | 45 | 48 |
| 2 | **Educational level (%)** | | | | | | |
| A | Illiterate | 43.3 | 40 | 33.3 | 50 | 43.3 | 56.7 |
| B | Primary | 13.3 | 13.3 | 0 | 16.7 | 11.7 | 16.7 |
| C | Secondary | 23.3 | 26.7 | 55.5 | 16.7 | 26.7 | 13.3 |
| D | Abovesecondary | 20 | 20 | 11.1 | 16.7 | 18.3 | 13.3 |
| 3 | **Family size (Numbers)** | 3 | 3 | 3 | 4 | 4 | 2 |

**Source:** Primary data collected from sample farm and non-farm households

**Extent, intensity and composition of indebtedness**

It is estimated that about 95 percent of sample farm households have borrowed credit from different sources and have outstanding dues in the study area. Similarly, 72 per cent of rural non-farm households have outstanding dues pending for repayment. Among different farm size groups, almost 10.0 per cent of small and marginal farmers have outstanding debts in this study area. Indebtedness is also observed among medium and large farmers to the extent of 89 per cent and 83 per cent respectively. This number is closely similar to reportings of NSSO (2014), where it was reported that 92 percent of farmers in Telangana state were indebted (NSSO, 2014).

Among the indebted farmers, one-third of them were noticed to have outstanding dues of Rs. 1,50,000 and above. Another one-fourth of indebted farmers have outstanding dues in the range of Rs. 50,000 to 1,50,000. About 45 per cent of indebted farmers have outstanding dues of less than Rs. 50,000 (Table 2).

**Table 3. Frequency distribution of sample non-farm households by level of indebtedness**

| S.No | Range of indebtedness | No of farm households | No of farm households in debt (%) |
|---|---|---|---|
| 1 | >1,50,000 | 12 | 28 |
| 2 | 50,000-1,50,000 | 15 | 35 |
| 3 | <50,000 | 33 | 77 |

**Source:** Primary data collected from sample farm households
Highest outstanding debt of farm households - 4,00,000
Lowest outstanding debt of farm households - 0
(3 members)

Average total borrowings and outstanding dues were computed and presented in Table 4 & 5. Results indicate that each farm households have borrowed on an average Rs.1,76,842, of which 82 per cent was from non-institutional sources such as private moneylenders, friends and relatives.

**Table 4. Total borrowing of sample farm and non-farm rural households (Rs /household)**

| S.No | Particulars | Farm house holds N=57 | Non-farm house holds N=43 |
|---|---|---|---|
| 1 | **Average total borrowing** | 1,76,842.1 | 1,78,511.6 |
| 2 | **% from Source of borrowing** | | |
| A | Institutional | 18.1 | 0.78 |
| B | Non-institutional | 81.9 | 99.22 |
| 3 | **Rate of interest(%/year)** | | |
| A | Institutional | 12 | 12 |
| B | Non-institutional | 38.3 | 35 |

N : Number of sample households
Source : Primary data collected from sample farmers

The institutional sources have almost neglected rural non-farm households in providing required credit in the study area. It implies that private money lenders, friends, relatives and local traders are major sources of total borrowings in which rate of interest was more than 35 per cent per annum. This is the root cause for accumulated outstanding dues, thereby causing indebtedness in the rural areas.

Among the farmers, the average borrowings of marginal farmers was Rs. 1,55,689, of which 90 per cent was borrowed from non-institutional sources. In the case of large farmers, average borrowings were Rs. 2,50,000 with 65 per cent of them borrowed from non-institutional sources. The results from Table 5 clearly imply that accessibility to institutional credit is very poor for small and marginal farmers, while large farmers have relatively better access to institutional credit. This could be a potential reason for higher indebtedness among small and marginal farmers.

The total outstanding dues an on average after repaying to a part of the total borrowings was Rs.1,02,656 and Rs. 1,34,241 for farms and non-farms respectively. The average outstanding dues were higher for medium farmers, followed by marginal farmers and large farmers. As a whole, the results showed that the intensity of indebtedness was highest among marginal farmers compared to others.

**Table 5. Total borrowings by sample farm households by different farm groups (Rs/household)**

| S.No | Particulars | Marginal N=29 | Small N=15 | Medium N=8 | Large N=5 | Average |
|---|---|---|---|---|---|---|
| 1 | **Average total borrowing** | 1,55,689.7 | 1,88,000 | 1,86,875 | 2,50,000 | 1,76,842.1 |
| 2 | **% from Source of borrowing** | | | | | |
| A | Institutional | 9.63 | 15.6 | 33.11 | 36 | 18.05 |
| B | Non-institutional | 90.37 | 84.4 | 66.89 | 64 | 81.95 |
| 3 | **Rate of interest (% / year)** | | | | | |
| A | Institutional | 13.71 | 14.4 | 12 | 12 | 12.012 |
| B | Non-institutional | 36 | 38.8 | 24 | 64 | 38.3 |

N : Number of sample farm size
Source : Estimated based on primary data collected for this study

In case of non-farm households, average borrowings were worked out at Rs.1,78,512. It is very pertinent to note that almost 100 per cent of borrowings by non-farm households were from non-institutional sources only in the study area. It may be concluded that the access to institutional credit to the farmers was only less than 20 per cent of the total credit requirements.

The results on the number of farm and non-farm households who borrowed for various purposes are presented in Table 6. Among farm households, most of them (50 out of 57) have borrowed for agricultural purposes, followed by 15 farmers for medical purposes and 10 farmers each for education and housing purposes. In contrast to the wide spread perception, only eight farmers have borrowed an on average of Rs.1,23,333 for various social events. However, the primary purpose for which most of the non-farm households borrowed was either for housing or medical or social needs. The possible reasons for more borrowings by non-farm households are the lack of non-farm income sources in the village, poor assets owned by them, and the increased cost of health, education and housing.

**Perceptions on reasons for indebtedness**

Apart from objective assessment based on primary data, a subjective assessment was also carried out to understand perceptions of sample households regarding reasons for indebtedness. Garrett rankings were estimated for each of the reasons based on the perceptions of sample households and same are presented in Tables 7 and 8. It is revealed from Table 7 that increased cost of farming was considered as the most important reason for causing indebtedness among farmers followed by declining farm income, high rate of interest by private moneylenders and easy access to non-institutional credit. Further inadequate institutional credit was also a major reason for indebtedness among the farmers. In addition, increased expenditure on health and education were also emerging as important reasons for indebtedness.

The Garrett's rankings for various reasons, perceived by non-farm households (Table 8), indicate that low non-farm income was the major reason for indebtedness among them. The other serious reasons are increased expenditure on self-employment activities; increased health expenditure and easy access to non-institutional credit at higher rate of interest are responsible for indebtedness among non-farm households.

**Table 6. Purpose-wise borrowing by sample farm and non-farm households (Rs/household)**

| Purpose | Farm households | | Non-farm households | |
|---|---|---|---|---|
| | N | Amount | N | Amount |
| Crop loan | 50 | 1,35,300 | 0 | 0 |
| Housing | 10 | 1,50,000 | 21 | 1,51,428.6 |
| Medical | 15 | 50,000 | 24 | 60,250 |
| Education | 10 | 66,500 | 7 | 1,24,285.7 |
| Social | 3 | 1,23,333.3 | 10 | 1,88,000 |

**N** : Number of sample households
**Source :** Estimated based on primary data collected for this study

**Table 7. Garrette's ranking of sample farmers on reasons for indebtedness**

| S. No | Perceptions | Average score | Rank |
|---|---|---|---|
| 1 | Increased cost of farming | 69.4 | 1 |
| 2 | Increased health expenditure | 53.8 | 6 |
| 3 | Increased education expenditure | 49.4 | 7 |
| 4 | Increased social expenditure | 42.5 | 8 |
| 5 | Inadequacy of institutional credit | 57.4 | 5 |
| 6 | Easy access to non-institutional credit | 58.3 | 4 |
| 7 | High rate of interest on non- institutional loan amount | 58.7 | 3 |
| 8 | Low farm income | 60.4 | 2 |
| 9 | Ancestral debt | 20.0 | 11 |
| 10 | Harsh recovery methods of Money lenders | 35.8 | 10 |
| 11 | Tenancy | 39.2 | 9 |

**Table 8. Garrett's ranking of sample non-farmhouse holds on reasons for indebtedness**

| S.No | Perceptions | Average score | Rank |
|---|---|---|---|
| 1 | Increased expenditure on self-employmentactivities | 60.7 | 2 |
| 2 | Increased health expenditure | 59.1 | 3 |
| 3 | Increased education expenditure | 48.4 | 8 |
| 4 | Increased social expenditure | 50.8 | 6 |
| 5 | Inadequacy of institutional loan amount | 50.8 | 7 |
| 6 | Easy access to non-institutional credit | 57.2 | 4 |
| 7 | High rate of interest on non- institutional loan amount | 53.7 | 5 |
| 8 | Low non-farm income | 66.8 | 1 |
| 9 | Ancestral debt | 18.6 | 10 |
| 10 | Harsh recovery methods of Money lenders | 28.8 | 9 |

**Source** Primary data collected from non-farm households

It is estimated that about 95 per cent of sample farm households have borrowed credit from different sources and have outstanding dues in the study area. Similarly, 72 per cent of rural non-farm households have outstanding dues pending for repayment. Among the indebted farmers, one-thirds of them had outstanding dues of Rs. 1,50,000 and above. Similarly, three-fourths of the non-farm households have outstanding dues with less than Rs. 50,000. Each farm households has borrowed on an average Rs.1,76,842, of which 82 per cent was from non- institutional sources. In case of non-farm households, average borrowings were worked out at Rs. 1,78,512.

It is very pertinent to note that almost 100 per cent of borrowings by non-farm households were from non-institutional sources such as private money lenders at interest rate of more than 35 per cent per annum. This is the root cause for accumulated outstanding dues, thereby causing indebtedness in the rural areas. Increased cost of farming was considered as the most important reasons for causing indebtedness among farmers followed by declining farm income, high rate of interest by private moneylenders and easy access to non-institutional credit. Similarly, low non-farm income was the major reason for indebtedness among non-farm households followed by increased expenditure on self-employment activities and increased health expenditure.

The results suggest that there is an urgent need to strengthen the public education and health systems with higher investments, to create non-farm income sources through massive rural industrialization and to increase credit flow from institutional sources to the rural sector.

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Research Note
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# SCREENING OF GERMPLASM LINES AGAINST SAFFLOWER WILT CAUSED BY *FUSARIUM OXYSPORUM* F. SP. *CARTHAMI*

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Safflower (*Carthamus tinctorius* L.) occupies prominent place in the agricultural wealth and economy of India. It belongs to family Compositae and believes to be native of Afghanistan. The word Carthamus is arabic word quartum (means the colour of dye obtained from florets). It is described as "Kusumbha" in ancient Sanskrit literature. Other Indian names, like Kusum, Karrad (Hindi), Kusumpuli (Bengali), Kusumbo (Gujrathi), Kardi, Kurdi (Marathi), Sendurakam (Tamil), Kusuma (Telgu), Kusube, Kusume (Kannada), Kusumba (Punjabi) seem to have been derived from "Kusumbha". Present the most common name being "Kusum" or "Kardi". It is a rich source of proteins and edible oil and so many farmers plant it.

Safflower is known to be infected by 57 pathogens including 40 fungi, two bacteria, 14 viruses and one mycoplasma (Patil *et al*. 1993). Amongst the fungal diseases Fusarium wilt caused by *Fusarium oxysporum* f. sp. *carthami* is one of the most notorious pathogen (Klisiewicz and Houston 1962). The infected plants show symptoms such as wilting, leaf yellowing and head blight (Weiss 1983). The disease can cause severe damage and yield reductions (Smith 1996). Wilt disease is economically most important disease of safflower in India. Repeated use of wilt- susceptible traditional varieties is considered the major factor causing increased incidence of wilt in this crop (Sastry *et al*., 1993). Breeding for disease resistance is the most economical and convenient method for controlling major diseases of safflower. Though, germplasm lines or cultivars showing partial or full resistance to some of the major diseases have been identified, the availability of genetic resistance is found to be rare. Though number of resistance sources identified against wilt across the globe, as mentioned above, continuous change in the genetic makeup of pathogen warrants continuous search for host resistance.

To overcome this problem, the present study was carried out with an objective to find out germplasm lines with resistance to wilt.

The experiment was carried out at College of Agriculture, Rajendranagar, PJTSAU, during *Rabi* season 2019-20. The experiment was conducted in randomized block design. Each germplasm line was sown in 3 m in a single row with 45 × 20 cm spacing as closer distance favours disease development.

The experimental material for the present study comprised of 41 safflower germplasm lines was collected from ARS, Tandur and recommended agronomic practices and insect pest control measures were followed and recording the disease intensity under field condition, 0 to 9 rating scale developed by Mayee and Datar (1986) was used (table 1). Further, the germplasm lines were categorized as immune, resistant, moderately resistant, susceptible and highly susceptible based on the score assigned during evaluation for *Fusarium oxysporum* f. sp. *carthami.*

$$\text{PDI} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

To find out the sources of host resistance against safflower wilt during *Rabi* 2019-20, a total of 41 safflower germplasm lines were screened against wilt disease in wilt sick plot. The results of experiment presented (Table 2) revealed that all the 41 germplasm lines of safflower showed different reactions against wilt disease during *Rabi* 2019-20. On the basis of wilt incidence, germplasm lines were categorized for their reaction to wilt as per rating. Accordingly the germplasm

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**Table 1. Disease rating scale (Mayee and Datar, 1986)**

| Disease scale | Particulars | Reaction |
|---|---|---|
| 0 | No wilting symptoms | Immune |
| 1 | <1% plants wilted | Resistant |
| 3 | 1-10% plants wilted | Moderately resistant |
| 5 | 11-20% plants wilted | Tolerant |
| 7 | 21-50% plants wilted | Susceptible |
| 9 | >51% plants wilted | Highly susceptible |

lines were grouped as disease immune, resistant, moderately resistant, susceptible and highly susceptible categories.

In *Rabi*, 2019-20 most of the germplasm lines were found are effective to reduce incidence of safflower wilt. A range of 0.0 to 53.33 per cent wilt incidence was recorded against susceptible check PBNS-12 in which 60.0 per cent disease incidence was recorded. The results indicated that among the 41 germplasm lines were tested for their resistance to wilt caused by *Fusarium oxysporum* f. sp. *carthami.* 13 germplasm lines *viz.*, TSF-1 (RC), GMU-7583, GMU-7585, GMU-977, GMU-1217, GMU-7574, TSF-84, TSF-64, TSF-85, TSF-87, TSF-71, SSF-1350 and SSF-1305 were immune, three germplasm lines *viz.,* GMU-7634, GMU-1799 and TSF-28 were moderately resistant, three germplasm lines viz., GMU-7618, GMU-7578 and TSF-86 were tolerant, 19 germplasm lines *viz.,* GMU-1095, GMU-4610, GMU-1777, GMU-1070, GMU-2424, GMU-777, GMU-961, GMU-4546, GMU-1693, GMU-7633, GMU-7608, GMU-1193, GMU-253, GMU-1802, GMU-1840, GMU1830, GMU-6098, GMU-6886 and Manjira were susceptible and three germplasm lines *viz.,* A1, PBNS-12 and Nira were highly susceptible to the test pathogen (Table 3).

It is also observed in earlier studies of Murumkar et al. (2008) who evaluated nine safflower varieties against wilt under sick plot conditions. They reported that none of the popular varieties (Bhima, Phule Kusuma, Sharada, Manjira, PBNS-12, A-l, JSI-7) were immune or resistant to wilt disease. Only two hybrids NARI-NH-1, DSH129 and one non-spiny variety NARI-6 recorded least disease intensity.

Similar a screening trail conducted by Kalpana Sastry and Chattopadhyay (2003) screen with 51 promising safflower germplasm lines in Fusarium wilt-infested plot resulted in identification of highly wilt-resistant selections viz., 86-93-36A, 237550, VI-92-4-2 and II-13-2A, with moderate resistance in HUS-305. These findings suggest that, it is possible to improve an existing elite line through further selection and screening of the progenies of the parental line.

**Table 2. Screening of elite lines against safflower wilt caused by *Fusarium oxysporum* f. sp. *Carthami***

| S. No | Entry | PDI | Reaction |
|---|---|---|---|
| 1 | Nira | 53.33 (46.91) | HS |
| 2 | PBNS-12 (SC) | 60.00 (50.80) | HS |
| 3 | TSF-1 (RC) | 0.0 (0.00) | I |
| 4 | GMU-7578 | 14.28 (22.2) | T |
| 5 | GMU-1095 | 30.00 (33.16) | S |
| 6 | GMU-4610 | 37.86 (37.95) | S |
| 7 | GMU-7583 | 0.00 (0.00) | I |
| 8 | GMU-1777 | 28.72 (32.38) | S |
| 9 | GMU-977 | 0.00 (0.00) | I |
| 10 | GMU-1070 | 30.95 (33.77) | S |
| 11 | GMU-2424 | 36.67 (37.23) | S |
| 12 | GMU-7585 | 0.00 (0.00) | I |
| 13 | GMU-777 | 31.19 (33.88) | S |

Table 2. (Cont.)

| S. No | Entry | PDI | Reaction |
|---|---|---|---|
| 14 | GMU-961 | 30.95 (33.77) | S |
| 15 | GMU-4546 | 33.57 (35.37) | S |
| 16 | GMU-1693 | 29.17 (32.62) | S |
| 17 | GMU-7633 | 40.66 (39.60) | S |
| 18 | GMU-7608 | 34.52 (35.97) | S |
| 19 | GMU-7634 | 10.24 (18.30) | MR |
| 20 | GMU-1799 | 6.90 (15.22) | MR |
| 21 | GMU-1193 | 37.86 (37.95) | S |
| 22 | GMU-253 | 30.95 (33.77) | S |
| 23 | GMU-1802 | 24.44 (29.60) | S |
| 24 | GMU-7618 | 13.33 (21.4) | T |
| 25 | GMU-1840 | 26.92 (31.19) | S |
| 26 | GMU1830 | 25.00 (29.93) | S |
| 27 | GMU-6098 | 17.86 (24.88) | S |
| 28 | GMU-1217 | 0.00 (0.00) | I |
| 29 | GMU-6886 | 36.67 (37.23) | S |
| 30 | GMU-7574 | 0.00 (0.00) | I |
| 31 | TSF-28 | 10.47 (18.57) | MR |
| 32 | TSF-64 | 0.00 (0.00) | I |
| 33 | TSF-71 | 0.00 (0.00) | I |
| 34 | TSF-84 | 0.00 (0.00) | I |
| 35 | TSF-85 | 0.00 (0.00) | I |
| 36 | TSF-86 | 16.67 (23.98) | T |
| 37 | TSF-87 | 0.00 (0.00) | I |
| 38 | SSF-1305 | 0.00 (0.00) | I |
| 39 | SSF-1350 | 0.00 (0.00) | I |
| 40 | Manjira | 36.04 (36.88) | S |
| 41 | A1 | 51.67 (45.94) | HS |
| | C.D. | 4.18 | |
| | SE(m) | 1.45 | |

*Mean of two replications
*In parentheses is angular transformed value
I-Immune, R-Resistant, MR-Moderately resistant, T-Tolerant, S-Susceptible, HS-Highly susceptible

**Table 3. Grouping of germplasm lines against safflower wilt disease**

| Disease scale | Particulars | Disease reaction | Germplasm lines |
|---|---|---|---|
| 0 | No wilting symptoms | I-Immune | 13 (TSF-1 (RC), GMU-7583, GMU-7585, GMU-977, GMU-1217, GMU-7574, TSF 84, TSF-64, TSF-85, TSF-87, TSF-71, SSF-1350 and SSF-1305) |
| 1 | <1% plants wilted | R-Resistant | Nil |
| 3 | 1-10% plants wilted | MR-Moderately resistant | 3 (GMU-7634,GMU-1799 and TSF-28) |
| 5 | 11-20% plants wilted | T- Tolerant | 3 (GMU-7618, GMU-7578and TSF-86) |
| 7 | 21-50% plants wilted | S-Susceptible | 19 (GMU-1095, GMU-4610, GMU-1777, GMU-1070, GMU-2424, GMU-777, GMU-961, GMU-4546, GMU-1693, GMU-7633, GMU-7608, GMU-1193, GMU-253, GMU-1802, GMU-1840, GMU1830, GMU-6098, GMU-6886 and Manjira) |
| 9 | >51% plants wilted | HS-Highly Susceptible | 3 (PBNS-12(SC)) + NIRA + A1) |
| | Total | | 38+ (PBNS-12 (SC) + NIRA+ TSF-1 (RC) |

SC- Susceptible check; RC- Resistant check

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