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DISSIPATION KINETICS AND DIETARY RISK OF EMAMECTIN BENZOATE IN GRAPES USING LIQUID CHROMATOGRAPH-MASS SPECTROMETRY

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ABSTRACT

The study aim was to find out how emamectin benzoate disappears and is leaving terminal residues in grapes. Modified QuEChERS method was developed, validated in Liquid Chromatograph-Mass Spectrometry (LC-MS) and used for estimating the residues of emamectin benzoate. The method linearity was good ($R^2 > 0.99$) and its Limit of Quantification (LOQ) was determined as 0.01 mg/kg. Relative standard deviation (RSD) was found to be less than 5% for the average recoveries obtained, ranged from 99.77 to 102.44 %. Emamectin benzoate half-life in grapes at single (11 g a.i/ha) dose (X) and double (22 g a.i/ha) dose (2X) was 1.11 and 1.22 days, respectively. The calculated hazard quotient (HQ) was found evident and cause negligible risk in terms of health hazard to consumers due to intake of emamectin benzoate residues through grapes at both studied doses.

Keywords: Dissipation, Emamectin benzoate, Grapes, Method validation, Risk assessment

INTRODUCTION

Among the commercial fruit crops, grapes (*Vitis vinifera* L.) is one of the most regularly cultivated crop in India's subtropical areas. India ranks seventh in the world in terms of grape production with 3.95 MT with cultivated area of about 1,50,000 ha and productivity of 21 MT ha^{-1}. Grape has become profitable horticultural crop, among all the fruit crops in recent years accounting for 2.01 % of total area under fruits foreign export of about 313.57 million USD during the 2020-21 period alone (APEDA, 2021). Among the various grape growing states, Maharashtra leaves its competitors far behind with 1,05,000 hectares and with the production of 2286 MT contributing 82 % of the total production in the country. The other major grape growing states include Karnataka (12.9%), Tamil Nadu (1.7%), Andhra Pradesh (1.3%) and Mizoram (0.8%). In Tamil Nadu, grapes are cultivated over 2200 hectares, with a total yield of 58.93 MT and a productivity of 27.27 MT ha^{-1} (GoI, 2019).

Multiple insect pests are known to inflict significant damage to grapes. Among these

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insect pests, most are found in the vegetative phase of the crop, but thrips (*Rhipiphorothrips cruentatis* Hood) infests the crop in both vegetative and reproductive stages. Thrips is a serious grape pest that can reduce marketable yields up to 50% and it may be found in all of India's major grape-growing regions. (Ranganath *et al.,* 2008). Emamectin benzoate is an insecticide derived from the fermented actinomycete, *Streptomyces avermitilis* product avermectin is registered and recommended against thrips in grapes by the Central Insecticide Board and Registration Committee (CIBRC, 2021). It has a minimum of 90% salts of avermectin B1a benzoate and a maximum of 10% avermectin B1b benzoate (Fig.1.) Emamectin benzoate causes insect paralysis and death within 2–4 days after intake is given to target insects by increasing the release of -aminobutyric acid (GABA).

Due of its effectiveness and activity on a vast scale, emamectin benzoate was used as plant protection input on a wider array of fruits and vegetables (Xie *et al.,* 2011). Unsurprisingly, emamectin benzoate is often used indiscriminately against a diverse array of grape insect pests (Yadav *et al.,* 2016; Patil *et al.,* 2017). Pesticides applied to crops may react with the surfaces of the plants, be affected by environmental variables such as wind and sun, or be wiped away during rain. The pesticide can be volatilized, chemically degraded, or microbially degraded while still on the crop surface. There are no investigations on the dissipation of emamectin benzoate in grapes to date from India. Since grape is an extensively consumed fruit valued for its mature berries, dissipation pattern and withholding period of harvest for emamectin benzoate on grapes must be studied in order to ensure food safety.

MATERIALS AND METHODS

Chemicals

Reference Standard of emamectin benzoate (98.0%), anhydrous sodium citrate dibasic sesquihydrate (99% purity) were provided by Sigma Aldrich, India. Sisco Research Laboratories (Mumbai,India) provided the HPLC grade acetonitrile (97%). Sodium Chloride analytical grade (99%) and Lichrosolv (LCMS) grade acetonitrile (> 99.9%) were purchased from Merck, Mumbai, India and anhydrous magnesium sulphate (≥99%) was supplied by Himedia Laboratories, Mumbai, India. Agilent Technologies (USA) provided Graphitised Carbon Black (GCB) and Primary Secondary Amine (PSA, 40 µm). Formic acid (≥99%) was supplied by Fisher Scientific Limited (Czech Republic). The commercial formulation of emamectin benzoate 5% SG was purchased locally from pesticide vendor in Theni, Tamil Nadu, India.

Standard solution preparation

A 400 mg/L emamectin benzoate individual stock solution was made in HPLC grade acetonitrile by measuring 10.24 mg emamectin benzoate analytical standard into volumetric flask (25 mL). In order to prepare a secondary stock solution of emamectin benzoate (40 mg/L), about 2.5 mL of the stock solution was relocated into a volumetric glass measuring 25 mL. A working standard mixture (10 mg/L) was made from secondary stock solution.

Field experiments

Dissipation study was carried out during December 2020 - February 2021 in a farmer's field of Kanniservaipatti Village of Theni district, Tamil Nadu, India (9^{o} N latitude, 76^{o} E longitude and 375 m above mean sea level) with all good agricultural practices. The trial was conducted on a $50m^2$ plot that had not been treated with emamectin benzoate before, and the treatments consisted of three replicated plots. The commercial product of emamectin benzoate was applied on grapes ('Muscat Hamburg' variety) at berry initiation stage (45 days after flowering) at the single (X) dose (11 g) and double (2X) dose (22 g) active ingredient per hectare. For the dissipation trial, power operated knapsack sprayer was used to apply two foliar sprays with an interval of ten days. During study period, maximum and minimum temperatures were recorded as 28.16 and 19.16^{o} C, respectively and relative humidity of 78.16% was recorded. Rainfall was not noticed and recorded during the study period.

Collection and preparation of samples

The grape berries for residue analysis were (0.5 kg) harvested from vines at random from each replication at 0 (2h), 1, 3, 5, 7, 10, 15, 20, 25, 30 and 35 days after spraying and harvest time samples. For residue analysis, samples were homogenised with a high-volume blade homogeniser (Robot Coupe) and stored in a deep freezer with -20^{o}C temperature.

Residue extraction and clean-up

QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) procedure (Anastassiades *et al.,* 2003) was adopted, modified and validated for analysis of samples. After adding 10 ml acetonitrile to a homogenised sample, 10 g of sample was taken in a centrifuge tube (50 mL) vigorously agitated for one minute. After adding anhydrous magnesium sulphate (4g) and sodium chloride (1g), the mixture was gently mixed before being centrifuged at 6000 rpm for 10 minutes. Following centrifugation, 6 mL was relocated to a new 15mL polypropylene centrifuge tube containing graphitized carbon black, primary secondary amine, magnesium sulphate with 10, 100 and 600 mg, respectively. After that vortex for one minute followed by centrifugation at 3000 rpm for ten minutes. A total of 1.0 mL was collected for emamectin benzoate residue analysis and the filtrate was immediately transferred to autosampler vials by the use of a 0.2µ membrane syringe filter.

LC-MS apparatus and chromatographic conditions

Emamectin benzoate residues were detected, estimated, and confirmed using Shimadzu 2020 series LCMS equipped with a reverse phase C_{18} (Eclipse plus- Agilent) column (250 mm length x 4.6 mm internal diameter, 5 µm particle size) at a column oven temperature of 40^{0}C. An 80:20 mix of acetonitrile and ultra-pure water comprising 0.1 percent formic acid was used as the mobile phase to elute and separate the emamectin benzoate from the samples. The liquid chromatograph mass-spectrometer pump was set up in binary mode with 0.5 mL/min flow rate and 48 kgf/cm^2 pressure to discharge the mobile phase in the aforementioned ratio. The chromatograms were analysed using shimadzu lab solutions software (5.6) and further calculations based on obtained peak areas in the chromatograms.

Samples were ionized using Electron Spray Ionization (ESI+) mode and 0.1 µA^{o} of interface current, temperatures of 350^{o} C, 250^{o} C for heat block and desolavation line (DL) respectively, nebulizer gas (N_2- 99.99%) flow of 1.5 L/minute, drying gas of 12 L/minute and scan speed of 15000 sec were employed.

Method validation parameters

For estimating emamectin benzoate residues in grapes, the method has been validated using SANTE guidelines (SANTE, 2019) and evaluated in terms of factors such as linearity, limit of detection (LOD), limit of quantification (LOQ), recovery, precision, repeatability, and matrix effect. A method acceptability in terms of reproducibility is shown by HorRat (Horwitz ratio) for intra-laboratory precision, calculated using the formula below (Horwitz & Albert, 2006).

HorRat = RSD/PRSD

Using the formula PRSD = 2 $C^{-0.15}$, we can calculate the expected RSD, where C is the mass fraction

Matrix Effect (ME) was assessed based on the formula mentioned by (Dong *et al.,* 2018).

$$\text{Matrix effect (\%)} = \frac{\text{Matrix match standard peak area} - \text{Solvent standard peak area}}{\text{Matrix match standard peak area}} \times 100$$

Data analysis

The final emamectin benzoate residue quantity was computed with the formula and chromatogram-derived parameters as follows

Residues (µg/g) =

$$\frac{As}{Astd} \times \frac{Wstd}{Ws} \times \frac{Vstd}{Asj} \times Vs(\text{final vol.})$$

A_s – Sample peak area

A_{std} – Standard peak area

W_{std} – Standard weight in ng

W_s – Sample weight in g

V_{std} –Standard volume injected in µl

V_s – Final sample extract volume in ml

A_{sj} – Sample injected in µl

The data from the field studies on emamectin benzoate residues was statistically analysed (Hoskins, 1961). Emamectin benzoate half-life was determined to be $T_{1/2}$ = 0.693/k. where k is slope from linear regression equation. The MRL for emamectin benzoate in grapes is 0.05 mg/kg, according to the European pesticide database (2021). The safe waiting period of emamectin benzoate was calculated using the formula mentioned by mentioned by (Handa *et al.,* 1999) as Safe waiting period = [log (A)-log (MRL)]/K.

Risk assessment

In order to arrive at the Hazard Quotient (HQ), EDI was divided by the acceptable daily intake (ADI). The HQ was then used to estimate the long-term toxicity of residue intakes based on pesticide toxicological data (Dong *et al.,* 2018). If HQ is more than 1, it is assumed that consumption of grapes is not safe and HQ less than 1 indicates, consumption of grapes is safe. Since MRL is not available under FSSAI (Food Safety Standard Authority of India, 2020), MRL of 0.05 mg/kg suggested by European Union (EU) was considered for risk assessment. ADI value of emamectin benzoate (FAO, 2011) is 0.0005 µg/g/bw/day. An Indian adult body weight is typically around 55 kg (Mukherjee & Gopal, 2000) and recommended total fruit consumption is 100 g/day (National Institute of Nutrition (NIN), 2011).

$$\text{EDI} = \frac{\text{Maximum residue concentration (mg/kg)} \times \text{daily intake of food (kg/ day)}}{\text{Average body weight of an adult (kg)}}$$

RESULTS AND DISCUSSION

Optimized LCMS Parameters

Instrument conditions were optimised using single quadrupole LC-MS to identify, confirm, and quantify emamectin benzoate residues in grapes. Using standard chromatographic conditions, at a retention time of 3.93 minutes, emamectin benzoate was isolated and eluted. Emamectin benzoate was quantified using Selective Ion Monitoring (SIM), and sensitivity was increased by using positive SIM mode with a target m/z of 887.

Method Validation

Recovery percentage, RSD, and linearity were estimated for the validation of analytical method used to identify and qunatify the emamectin benzoate residues in grapes. The linearity of the method ranged between 0.005 and 0.1 mg/L concentrations for grape matrices (Fig. 4). The correlation coefficient (r^2 value) for emamectin benzoate was greater than 0.99 for matrix-matched and solvent standards (Table 1). LOD and LOQ were established by comparing the signal-to-noise ratio of three and 10 to a blank sample's background noise. LOD and LOQ confirmed as 0.005, 0.01 µg/g, respectively Proposed LOQ (0.01 mg/kg) was within the MRL (0.05 µg/g) as proposed by European Union (EU Database, 2021). According to SANTE (2019), the obtained recoveries of emamectin benzoate in grapes were between 70 - 120 percent (Table 1). The standard and recovery chromatograms were given as figure 3 and 4. Precision was measured in terms of RSD ranged from 1.81 to 4.17% in grape matrix. In the spiked grape samples, the matrix effect was 2.14 - 7.66%. The HorRat (Horwitz ratio) of emamectin benzoate was less than 0.5 at all the levels spiked in grape matrices which was within the permitted range of 0.5 to 2.0 as suggested by SANTE (2019) standards. As a result, the analytical method exhibited acceptability with regards to intra-laboratory precision and accuracy.

Degradation kinetics of emamectin benzoate in grape berries

The mean initial emamectin benzoate residue in grapes was 0.068, 0.150 µg/g, at X and 2X dose, respectively. After foliar application, emamectin benzoate degraded quickly, reaching BDL (0.01 µg/g) three days after application at X dose and five days at the 2X dose, respectively (Table 2; Fig. 7). Various studies reported on dissipation of emamectin benzoate in different crops other than grapes as 1.3, 2.04, 2.75, 2.5 and 4.9 days in tea, paddy, apple, tomato and mango (Madasamy and Anandh, 2012; Li *et al.,* 2011; Wang *et al.,* 2012; Malhat *et al.,* 2013; Bian *et al.,* 2020). After foliar treatment of emamectin benzoate, the computed half-life in grapes showed (Fig. 2) that it may degrade rapidly as previous reports and it might be attributed due to physical and chemical properties of emamectin benzoate and growth dilution factor (Malhat *et al.,* 2014). In spite of registration by CIB & RC, no published reports were available for emamectin benzoate in grapes under Tamil Nadu Agroclimatic conditions. Hence, the study was undertaken in major grape growing area of Tamil Nadu to study dissipation and risk assessment of emamectin benzoate in grapes. Since dissipation pattern of pesticides varies with climatic conditions accordingly pre-harvest interval also will vary. Based on multilocation trials in different agro climatic regions of India, Central

Table 1. Recovery, linearity parameters and matrix effect of emamectin benzoate in grape matrix

Pesticides	Calibration (matrix)	Calibration range (mg/L)	Regression equation	Correlation coefficient (R^2)	Matrix effect (%)
Emamectin benzoate	Solvent	0.005-0.1	y = 4E+07x - 158382	0.9914	-
	Immature grapes	0.005-0.1	y = 9E+06x + 805.71	0.9979	2.14
	Mature grapes	0.005-0.1	y = 2E+07x - 38144	0.9982	7.66
Recovery of emamectin benzoate at different spiking levels (n=7)					
		Spiked concentration (µg/g)	**Recovery (%) ± Standard Deviation**	**Relative Standard Deviation (%)**	**Horwitz ratio (HorRat)**
Immature grapes		0.010	102.44 ± 3.22	3.14	0.10
		0.025	99.89 ± 2.82	2.82	0.10
		0.050	99.93 ± 1.81	1.81	0.07
		0.075	100.05 ± 4.17	4.17	0.18
		0.100	99.77 ± 3.66	3.67	0.16
Mature grapes		0.010	92.19 ± 2.89	3.13	0.10
		0.025	100.41 ± 2.37	2.36	0.09
		0.050	95.65 ± 4.49	4.70	0.19
		0.075	98.99 ± 2.11	2.13	0.09
		0.100	103.07 ± 3.46	3.36	0.15

Table 2. Residues, dissipation, dietary risk of emamectin benzoate in grape berries at 11 g a.i /ha (X) and 22 g a.i/ha (2X)

X dose						2X dose					
Days after application	Residues* (µg/g)	Dissipation (%)	Dietary Risk			Days after treatment	Residues* (µg/g)	Dissipation (%)	Dietary risk assessment		
			EDI	ADI	HQ				EDI	ADI	HQ
0 (2hrs)	0.068	-	0.000125	0.0005	0.250	0 (2hrs)	0.150	-	0.000277	0.0005	0.554
1	0.030	55.88	0.000054	0.0005	0.110	1	0.060	60.00	0.000112	0.0005	0.224
3	0.010	85.29	0.000018	0.0005	0.038	3	0.018	88.00	0.000032	0.0005	0.067
5	BDL	-	-	-	-	5	0.009	94.00	0.000016	0.0005	0.034
Harvest	BDL	-	-	-	-	Harvest	BDL	-	-	-	-
Kinetic equation	$y = -0.2629x + 1.8001$					$y = -0.2378x + 2.0898$					
R^2 value	0.9853					0.9644					
Half-life (days)	1.11					1.26					
Safe waiting period (days)	0.52					2.03					

BDL - Below detectable level (<0.01 µg/g), *Average of three replicates; ADI- Acceptable daily intake; EDI- Estimated daily intake, HQ- Hazard quotient

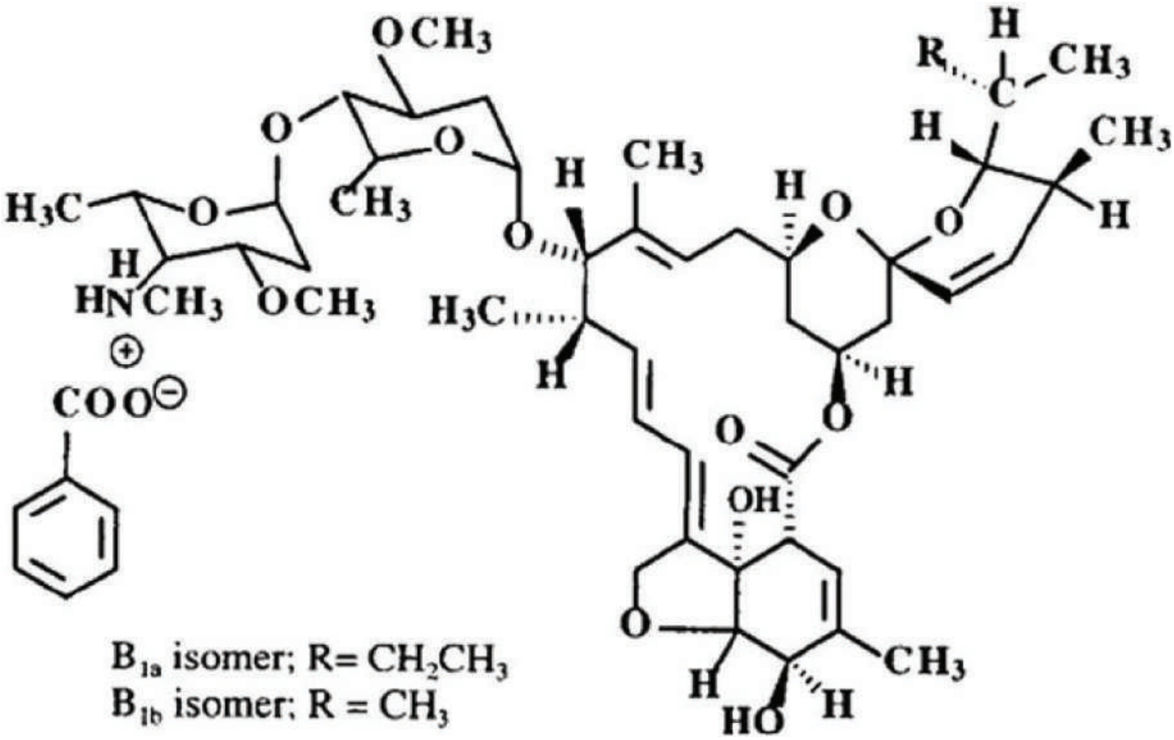


Fig. 1. Emamectin benzoate structure

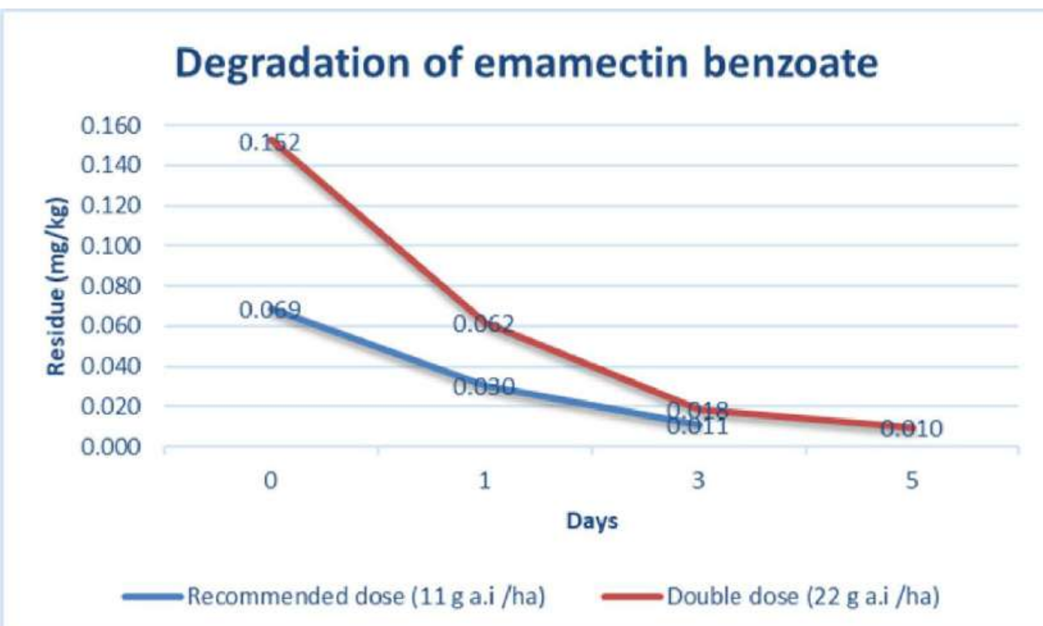


Fig. 2. Emamectin benzoate degradation in grapes

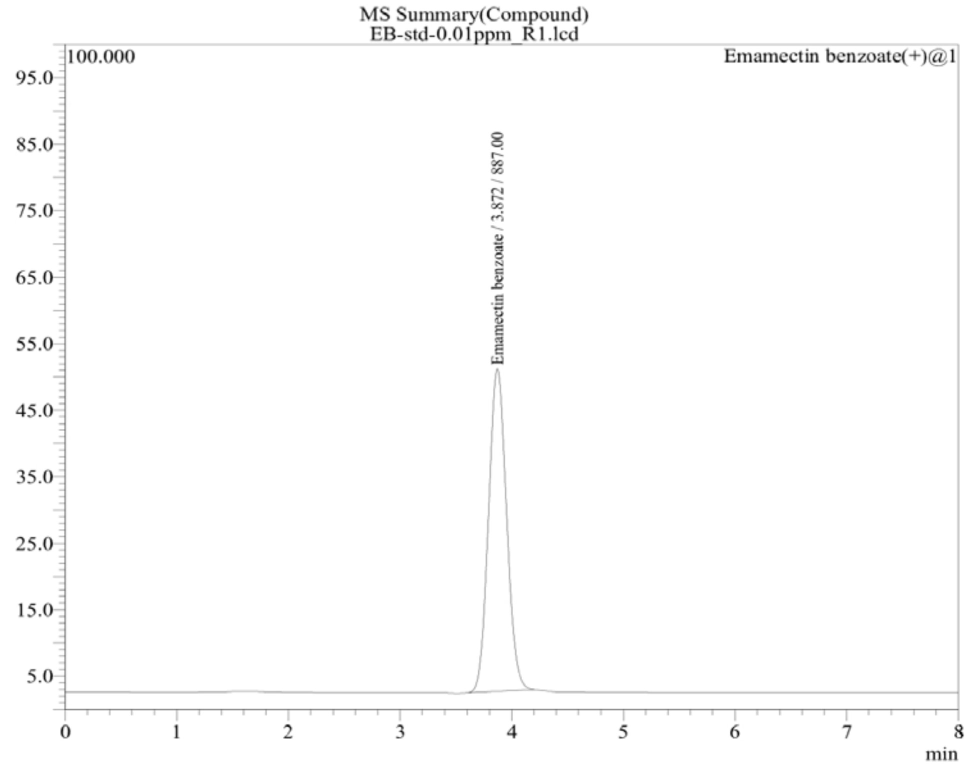


Fig. 3. Standard chromatogram of emamectin benzoate (0.01ppm)

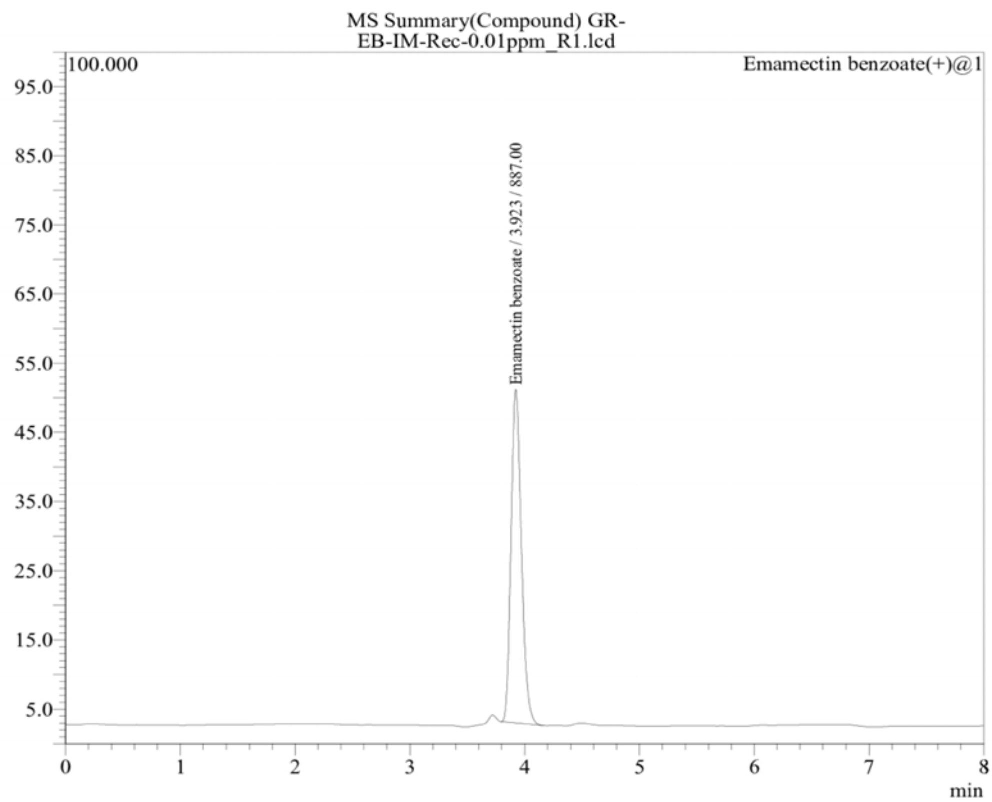
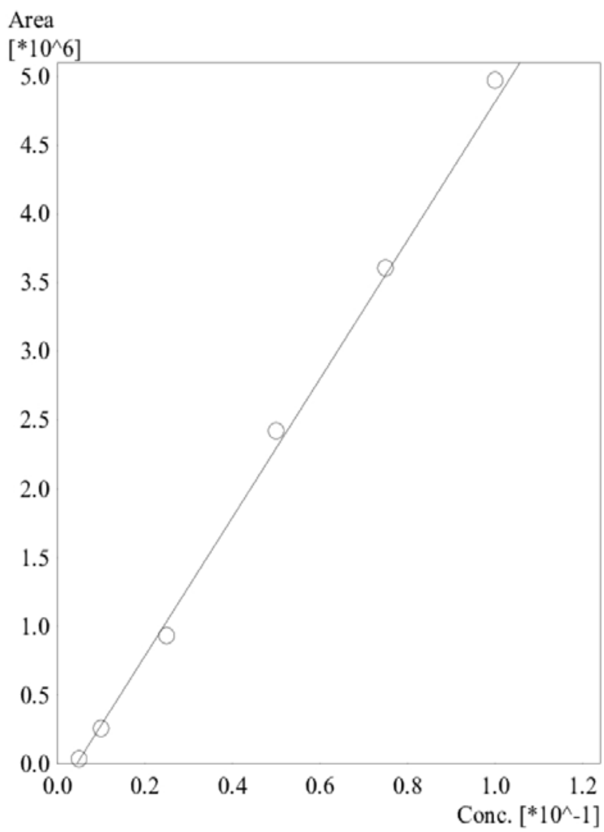


Fig. 4. Recovery chromatogram of emamectin benzoate (0.01ppm)

Calibration Curve

ID# : 1 m/z : 887.0000
Name : Emamectin benzoate
Quantitative Method : External Standard
Function : f(x)=5.04042e+007*x-226546
Rr1=0.9979403 Rr2=0.9958849
MeanRF: 3.593041e+007 RF SD: 1.608107e+007 RF %RSD: 44.756146
FitType : Linear
ZeroThrough : Not Through
Weighted Regression : 1/C^2



#	Conc.(Ratio)	MeanArea	Area
1	0.005	33190	31926
			35133
			32511
2	0.01	255643	245731
			256360
			264837
3	0.025	930346	921853
			960607
			908577
4	0.05	2419200	2521045
			2367259
			2369296
5	0.075	3604128	3662284
			3579360
			3570740
6	0.1	4972729	5010860
			5121830
			4785498

Fig. 5. Linearity curve of emamectin benzoate (0.005-0.1ppm)

Insecticide Board fixed a PHI of 5 days for emamectin benzoate in grapes and in the current study PHI calculated was less under current location of study (1& 2 days at recommended dose and double dose) and also it may be based on LOQ of method.This study could provide guidance for the safe use of emamectin benzoate and serve as a reference for the establishment of maximum residue limits (MRLs) in grapes along with other region data established by another researcher. Since, in India, no MRL has been fixed for emamectin benzoate with regard to grapes and by comparing the residue data with TMRC and MPI, residue of the day which gives TMRC MPI is fixed as MRL.

Dietary risk was calculated (Table 2) based on Indian consumption data and results stated that consumption of grapes after application of

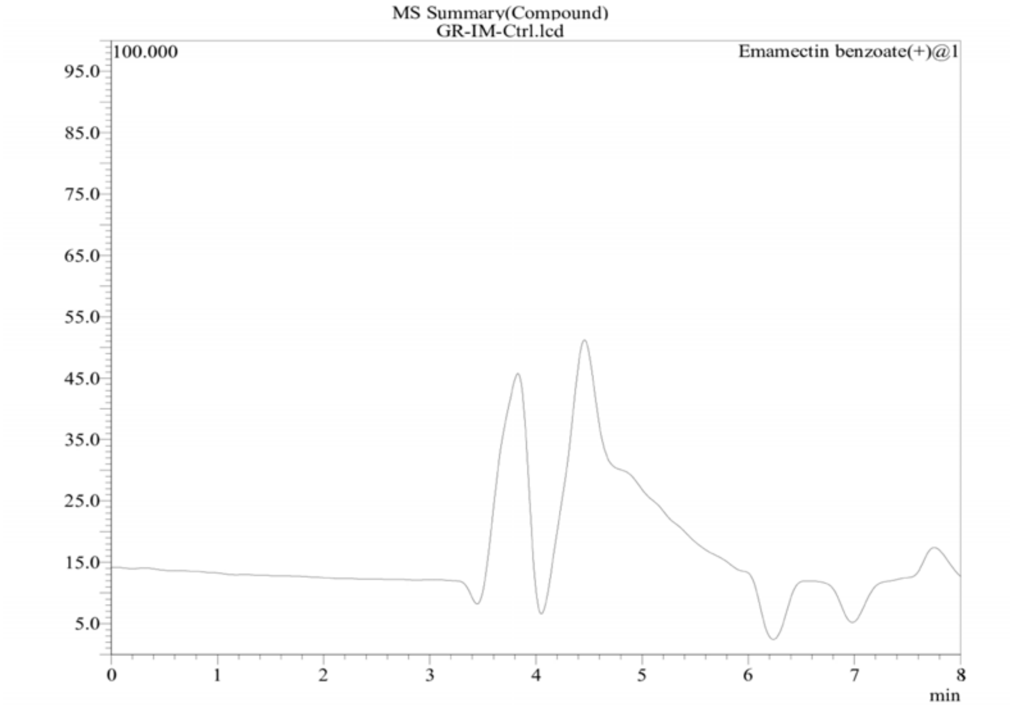


Fig. 6. Control chromatogram grapes

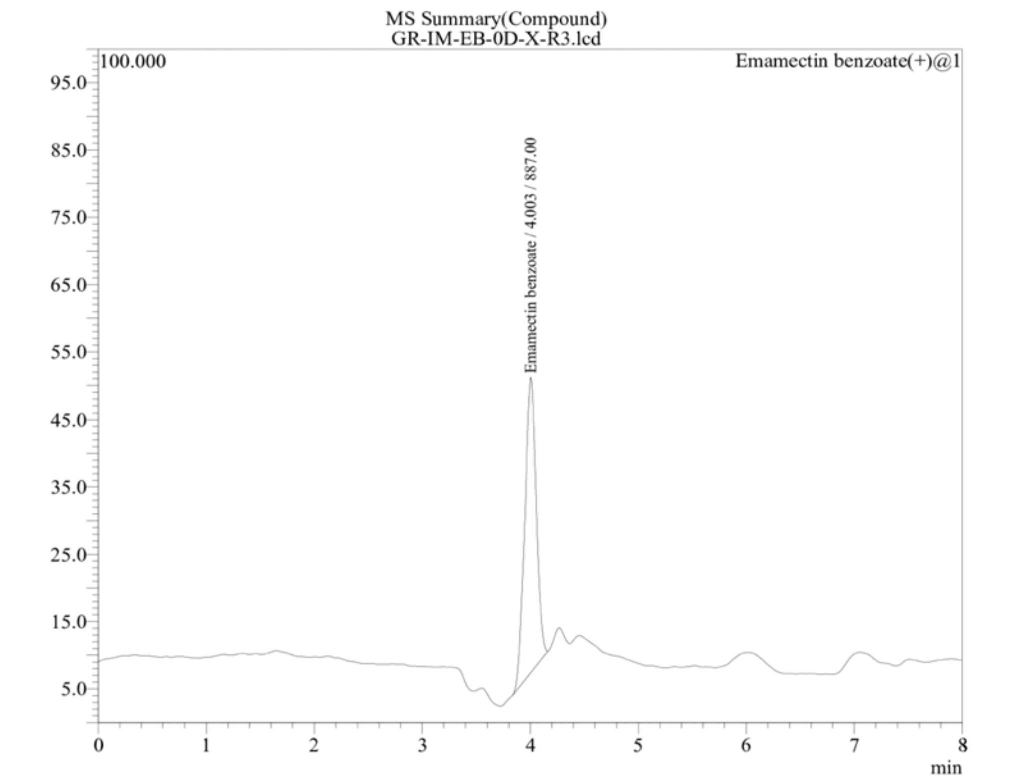


Fig. 7. Grape Sample chromatogram (0^{th} day)

emamectin benzoate by following Good Agricultural Practices (GAP) was found safer (HQ<1) to the consumers.

CONCLUSION

A modified QuEChERS protocol combined with LCMS used to estimate emamectin benzoate residues in grapes. Results showed that residues had a half-life of 1.11-1.26 days, indicating a rapid degradation of emamectin benzoate. The risk of emamectin benzoate to consumers was assessed to be negligible based on the HQ value. A one-day safe waiting period was proposed before harvesting grapes after foliar treatment of emamectin benzoate at suggested dose. According to the study, emamectin benzoate degraded swiftly and there were no adverse consequences on human health as well as the environment.

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EFFECT OF MUTAGENESIS ON GROWTH AND YIELD RELATED TRAITS IN BLACKGRAM (*Vigna mungo* (L.) Hepper)

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ABSTRACT

The investigation was conducted to understand the immediate effect of mutagenesis on growth and yield traits in blackgram in order to select most effective mutagen and its dose/concentration which induce desired improvement without disturbing the better attributes. The seeds of two varieties of blackgram *viz.,* LBG 752 and TBG 104 were treated with gamma rays (200 Gy, 300 Gy, 400 Gy, 500Gy and 600 Gy), EMS (Ethyl Methane Sulphonate) (0.2%, 0.3%, 0.4%, 0.5% and 0.6%) and MH (Maleic Hydrazide) (0.01%, 0.02% and 0.03%). The observations were recorded on seed germination, shoot length and root length under *in-vitro* condition and seedling emergence, seedling survival, seedling height, pollen fertility, plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod length, seed fertility, 100-seed weight and seed yield per plant under field condition. Higher doses of all the mutagens caused considerable reduction in all the traits studied. MH treatment resulted in drastic reduction in seedling characters *viz.,* seedling emergence, seedling survival and seedling height followed by EMS and gamma rays treatment. Based upon the sensitivity of mutagen, gamma rays were highly effective for modifying majority of the traits in the crop with less biological damage followed by EMS and MH treatments. Both the parental varieties differed themselves for mutagen treatments. The reduction in the traits with increasing dose of mutagens was more prominent in LBG 752 than TBG 104 indicated that LBG 752 was more sensitive to mutagen treatment. These findings would greatly help for cost effective selection of mutagen and variety for successful generation of variation in mutation breeding programmes aimed at blackgram crop improvement.

Key words: Blackgram, Gamma rays, EMS, MH, Mutagen and Sensitivity

INRODUCTION

Blackgram is an important food grain legume with easily digestable protein and low flatulence contents. Comparatively higher lysine content makes it an excellent complement to cereals in terms of balanced human nutrition. Being a short duration pulse crop, it is well suited to various seasons and cropping systems. It also

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enriches the soil fertility, improves the soil structure and used as nutritious fodder for cattle. In India, among the pulses, it ranks fourth in area and production after chickpea, pigeonpea and mung bean. India is the largest producer as well as consumer of the blackgram. However, the average yield of blackgram is very low in comparision to major grain legumes such as chickpea and pigeonpea. Hence, in view of its growing importance and its suitability to various cropping systems and nitches, the production potential of blackgram crop should be enhanced by developing high yielding genotypes. However, as the genetic variability is very low in this crop due to cleistogamous nature and narrow genetic base among the released cultivars, the progress of breeding programmes is not in pace with the growing demands. In this scenario, induced mutations can be considered as one of the viable alternatives to create variability which is a pre-requisite for any crop improvement programme.In order to induce mutations, both physical and chemical mutagens have been found promising in blackgram (Surendar and Vanniarajan, 2014; Usharani *et al.,* 2017 and Veni *et al.,* 2017). Among the physical mutagens, gamma rays are partially ionizing which directly penetrate into the plant tissue. Depending upon the radiation level, they can damage or modify important components of plant cells. Among the chemical mutagens, EMS generally producesinduced mutations that lead to mispairing or mismatch pairing in the DNA of a treated organism. Under these conditions, an alkylated G pairs with T in place of C, causing a G/C to A/T transition in the backbone of the DNA and MH is an effective chromosome breaker as it actspreferentially on heterochromatic region. These mutagens can be used to activate morphometric and reproductive changes in plants; and further selection of mutant plants through number of generations resulting in introduction of new traits into a treated population. Hence, understanding the effect of mutagenesis on blackgram in terms of growth and yield related traits is useful in order to select most beneficial mutagen or its dose/concentrationand also the genotype based on mutagenic sensitivity for establishment of mutation breeding programme in a cost effective manner.

Therefore, the study was conducted to understand the effect of three mutagens *viz.*, gamma rays, EMS and MH on seed germination, shoot length and root length, seedling emergence, seedling survival, seedling height, pollen fertility and other yield related traits in blackgram.

MATERIAL AND METHODS

The plant material in the investigation consisted of two promising blackgram varieties of Andhra Pradesh and Telangana *viz.,* LBG 752 and TBG 104. The seeds of these varieties were irradiated with five different doses of gamma rays *viz.,* 200 Gy, 300 Gy, 400 Gy, 500 Gy and 600 Gy at BARC, Trombay. Similarly, for chemical mutagen treatment, the seeds were treated with five different concentrations *viz.,* 0.2%, 0.3%, 0.4%, 0.5% and 0.6% of EMS and three different concentrations of MH *viz*., 0.01%, 0.02% and 0.03% in the Department of Genetics and Plant Breeding, Sri Venkateswara Agricultural College, Tirupati during *kharif*, 2017-18. The seeds of both the varieties were soaked for six hours in distilled water before the chemical mutagen treatment. The pre-soaked seeds after removal from the water were placed between folds of blotting paper to remove the water adhered on the surface. Then the seeds were immersed for six hours in the requisite concentration of mutagen with intermittent shaking. To ensure uniform absorption of the mutagen, the volume of the mutagen solution was maintained at a proportion of ten times to that of seed volume. The whole treatment was carried out at room temperature of 23±1^{0}C. Immediately after the completion of treatment duration, the treated seeds were thoroughly washed in running water for half-an-hour. A set of untreated seed served as control. A total of 75 treated seeds per treatment with respective control were kept for germination under *in-vitro* condition following completely randomized design with three replications. Five days after sowing, the seed germination percentage, shoot length and root length were recorded in each and every seedling.A total of 750 treated seeds per treatment with respective control were sown in the field in randomized block design with three replications during *kharif*, 2017 to study M_1 generation. The spacing adopted was 30 cm X 10 cm. Recommended dose of fertilizer, plant protection measures and the general cultural practices were uniformly followed for all the treatments. The observations on seedling emergence (%), seedling survival(%), seedling height (cm), pollen fertility (%), plant height (cm), number of primary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod length, seed fertility (%), 100-seed weight (g) and seed yield per plant (g) were recorded. These observations were taken on randomly selected 20 plants per treatment in each replication except seedling emergence and seedling survival. Observations were recorded on plot basis and the average performance was worked out.

RESULTS AND DISCUSSION

The data recorded on seed germination, shoot length and root length under *in-vitro* condition for LBG-752 and TBG-104 mutagen treated population were statistically analysed separately and the details of analysis of variance are furnished in Tables 1 and 2. The analysis of variance indicated significant treatment differences for all the three characters studied in gamma rays, EMS and MH treated population of both the varieties.

The results on effect of gamma rays, EMS and MH treatments on biological parameters like seed germination, shoot length and root length in LBG 752 and TBG 104 varieties of blackgram (Table 3) (Figs. 1 and 2) revealed that the significant reduction in mean seed germination percentage, shoot length and root length with few exceptions than their respective control was observed with increase in dose/concentration of all the mutagens in both the varieties. In LBG 752, seed germination percentage reduced from 98.33 percent (control) to 38.67 percent (600 Gy of gamma rays), 23.33 percent (0.6% EMS) and 18.00 percent (0.03% MH) at higher doses ofdifferent mutagens. Whereas, in TBG 104, it reduced from 99.33 percent (control) to 45.33 percent (600 Gy of gamma rays), 42.33 percent (0.6% EMS) and 46.33 percent (0.03% MH) at higher doses of different mutagens. In LBG 752, shoot length reduced from 16.71cm (control) to 8.71 cm (600 Gy of gamma rays), 2.87 cm (0.6% EMS) and 0.93 cm (0.03% MH) at higher doses of different mutagens. Whereas, in TBG 104 it reduced from 15.87 cm (control) to 7.74 cm (600 Gy of gamma rays), 1.58 cm (0.6% EMS) and 1.11 cm (0.03% MH) at higher doses of different mutagens.Similarly, root length in LBG 752 reduced from 4.52 cm (control) to 1.98 cm (600 Gy of gamma rays), 0.29 cm (0.6% EMS) and 1.10 cm (0.03% MH) at higher doses of different mutagens. Whereas in TBG 104, it reduced from 4.54 cm (control) to 2.81 cm (600 Gy of gamma rays), 0.41 cm (0.6% EMS) and 0.99 cm (0.03% MH) at higher doses of different mutagens. Such reports of reduction in seed germination, shoot and root length was also reported by Surendar and Vanniarajan (2014), Lavanya *et al.* (2016), Usharani *et al.* (2017) and Veni *et al.* (2017) in blackgram.

In the study, the high proportion of seed lethality due to mutagen treatment might be associated with weakening of intra-chromosomal linkage or accumulation of deleterious mutations in different genomes. The reduction in germination might be due to the alkylation of sulphahydral (-SH) group of important proteins causing death of the seeds (Ehrenberg and Lundquist, 1961). According to Rupinder and Kole (2005), severe reduction in plumule to radical length and physical injuries of radicles indicated that the root inhibition arises primarily from the effect on meristems by arresting the synthesis of growth stimulating auxins and consequent inhibition of cell division. The influence on shoot and root growth has been related to many factors which may be attributed to chromosomal abnormality with height reduction, reduction in auxin levels, inhibition of auxin synthesis, failure of assimilation mechanism and chromosomal damage cum mitotic inhibition (Riley, 1954).

The analysis of variance for the 13 traits studied under field condition (Tables 4 and 5) revealed the existence of significant differences among the treatments in both the genotypes. This reflects the existence of adequate genetic variability in the material that can be effectively exploited in various breeding programmes.

The observations on various traits in M_1 generation under field condition are presented in Tables 6, 7 & 8. Among the gamma rays treatments, seedling emergence ranged from 27.20 (600 Gy) to 78.13 percent (200 Gy) in LBG 752 and 38.40 (600 Gy) to 85.47 percent (200 Gy) in TBG 104 as against 91.87 percent (LBG 752) and 92.53 percent (TBG 104) in their respective control. Among EMSt reatments, there was a significant reduction in seedling emergence which ranged from 19.87 (0.6%) to 68.80 percent (0.2%) in LBG 752 and 39.33 (0.2%) to 86.67 percent (0.6%) in TBG 104. Among MH treatments, seedling emergence ranged from 11.87 (0.03%) to 15.60 percent (0.01%) in LBG 752 and 11.47 (0.03%) to 13.07 percent (0.01%) in TBG 104 (Table 6). According to Gaul (1964), the biological damage caused by mutation to germination, seedling survival, seedling height and pollen fertility may be considered as an indication of mutagenic effect and, hence, these traits are discussed in detail. Seedling emergence percentage, seedling survival percentage, seedling height and pollen fertility were significantly reduced over control with few exceptions in all the treatments with the increasing dose/concentration of mutagens in both the varieties (Table 6). The decrease in germination at higher doses of the mutagen treatment might be due to the disturbances at cellular level (caused either at physiological level or at physical level) including chromosomal damages or due to the combined effect of both (Khan and Tyagi, 2010). During early phase, the seedlings could adjust or repair themselves to eliminate the dead or unwanted cells. On the other hand, some of the seedlings might not able to overcome the radiation damage, and hence, might die before they put forth any side effects. According to Girija *et al*. (2013), seed germination which was simple growth of radicle and shoot, was apparently unaffected by embryo damage caused by irradiation treatment. However, embryo damage might become apparent only at the later stages of ontogenesis. This was evident from the results of the survival count where survival rate decreased with increasing levels of doses.

Among the gamma rays treatments, in case of LBG 752, pollen fertility ranged from 51.89 (600 Gy) to 89.27 percent (200 Gy) and in TBG 104 it ranged from 69.25% (600 Gy) to 84.72% (200 Gy) as against their respective control of LBG 752 (95.13 percent) and TBG 104 (87.63 percent). Among the EMS treatments, pollen fertility ranged from 25.17 percent (0.6%) to 63.86 percent (0.2%) in LBG 752, wherein TBG 104, it varied from 42.93 (0.6%) to 85.26 percent (0.2%). Among MH treatments, pollen fertility varied from 47.69 (0.03%) to 83.08 percent (0.01%) in LBG 752 and 31.63 (0.03%) to 76.68 percent (0.01%) in TBG 104 (Tables 6 and 7). Larik (1975) reported that the pollen fertility reduction might be due to cumulative effects of various aberrant meiotic stages as well as physiological and genetic damages that induce probably by the breakage of chromosomes through formation of an anti-metabolic agent in the cell or might be due to irregular disjunction of chromosomes at anaphase. In addition to chromosomal aberrations, some genetic and physiological changes might have caused pollen fertility reduction. Reduction of pollen fertility occurs due to inactivation of certain genes, thereby upsets genetic and physiological equilibrium, physiological disturbance, chromosome structural changes and point mutations (Gaul, 1977).

The significant reduction in the mean plant height, number of primary branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod length, seed fertility, 100-seed weight and seed yield per plant over control in both the varieties with few exceptions was observed with increased doses/ concentrations of gamma rays, EMS and MH treatments. Reduction of height was attributed to the elimination of damaged zones by inhibition of cell division and the growth of injured meristematic cells which replace the injured ones as growth proceeded (Louis and Kadambavanasundaram, 1973). The inhibition of growth was also reported due to slow rate of cell division, decreased amylase activity and increased peroxidase activity (Rao, 1988). In contrast to this, increase in plant height was also reported by Karthik (2008) in blackgram.

Other yield parameters such as number of primary branches per plant, number of clusters per plant, number of pod per plant, number of seeds per pod, pod length, seed fertility and seed yield per plant was found to be reduced drastically with higher doses/concentrations of mutagenic treatments in the two varieties as compared to their respective control. Seed yield per plant was recorded as 6.11 g and 5.82 g for controls LBG 752 and TBG 104, respectively. Among the gamma rays treatments, the range of this trait varied from 4.26 (600 Gy) to 5.91 g (200 Gy) in LBG 752 and 3.43 (600 Gy) to 5.10 g (200 Gy) in TBG 104. Among the EMS treatments, it ranged from 3.12 (0.6%) to 4.70 g (0.2%) in LBG 752 and 3.86 (0.6%) to 5.12 g

(0.2%) in TBG 104. Among MH treatments, it varied from 4.82 (0.03%) to 6.05 g (0.01%) in LBG 752 and 4.89 (0.03%) to 5.33 g (0.01%) in TBG 104 (Table 8).This might be anticipated in M_1 generation because of morpho-physiological changes and disturbed meiosis due to effect of various mutagenic treatments.Reduction in mean values of various traits due to various mutagenic treatments in blackgram had also been reported earlier by Surendar and Vanniarajan (2014), Usharani *et al.* (2017) and Veni *et al.* (2017). The factors that could be attributed for this inhibitory effect were failure of assimilatory mechanisms, inhibition of DNA synthesis and reduction of reactivity of IAA (Miura *et al.,* 1974).

Based on the overall consideration of the M_1 effects, among all the treatments, MH treatment resulted in drastic reduction in seed germination percentage followed by EMS and gamma rays treatments both under *in-vitro* and field conditions. In LBG 752, the mean of seed germination in gamma rays, EMS and MH treated populations was 68.94 percent, 60.11 percent and 58.83 percent, respectively. With respect to TBG 104, the mean of seed germination in gamma rays, EMS and MH treated populations was 76.88 percent, 76.83 percent and 68.24 percent, respectively. The mean of seedling emergence percentage was highest in gamma rays treated population (56.24% and 64.29 %) followed by EMS (51.59% and 65.56%) and MH treated population (33.24 % and 32.37 %) of LBG 752 and TBG 104, respectively. In the case of LBG 752, the mean of seedling survival in gamma rays, EMS and MH treated population was 54.14 percent, 49.23 percent and 35.12 percent, respectively. With respect to TBG 104, the mean of seedling survival in gamma rays, EMS and MH treated populations was 61.71

Table 1. Analysis of variance for three characters in M_1 generation ofLBG 752 under *in-vitro* condition

S. No.	Characters	Mean sum of squares	
		Treatments (df: 13)	Error (df: 28)
1.	Seed germination (%)	1721.19**	8.05
2.	Shoot length (cm)	75.04**	3.06
3.	Root length (cm)	4.98**	0.41

** Significant at 1% level

Table 2. Analysis of variance for three characters in M_1 generation ofTBG 104 under *in-vitro* condition

S. No.	Characters	Mean sum of squares	
		Treatments (df: 13)	Error (df: 28)
1.	Seed germination (%)	1274.86**	10.19
2.	Shoot length (cm)	59.12**	1.64
3.	Root length (cm)	5.22**	0.68

** Significant at 1% level

Fig. 1. Effect of mutagens on germination, shoot length and root length in M_1 generation of LBG 752

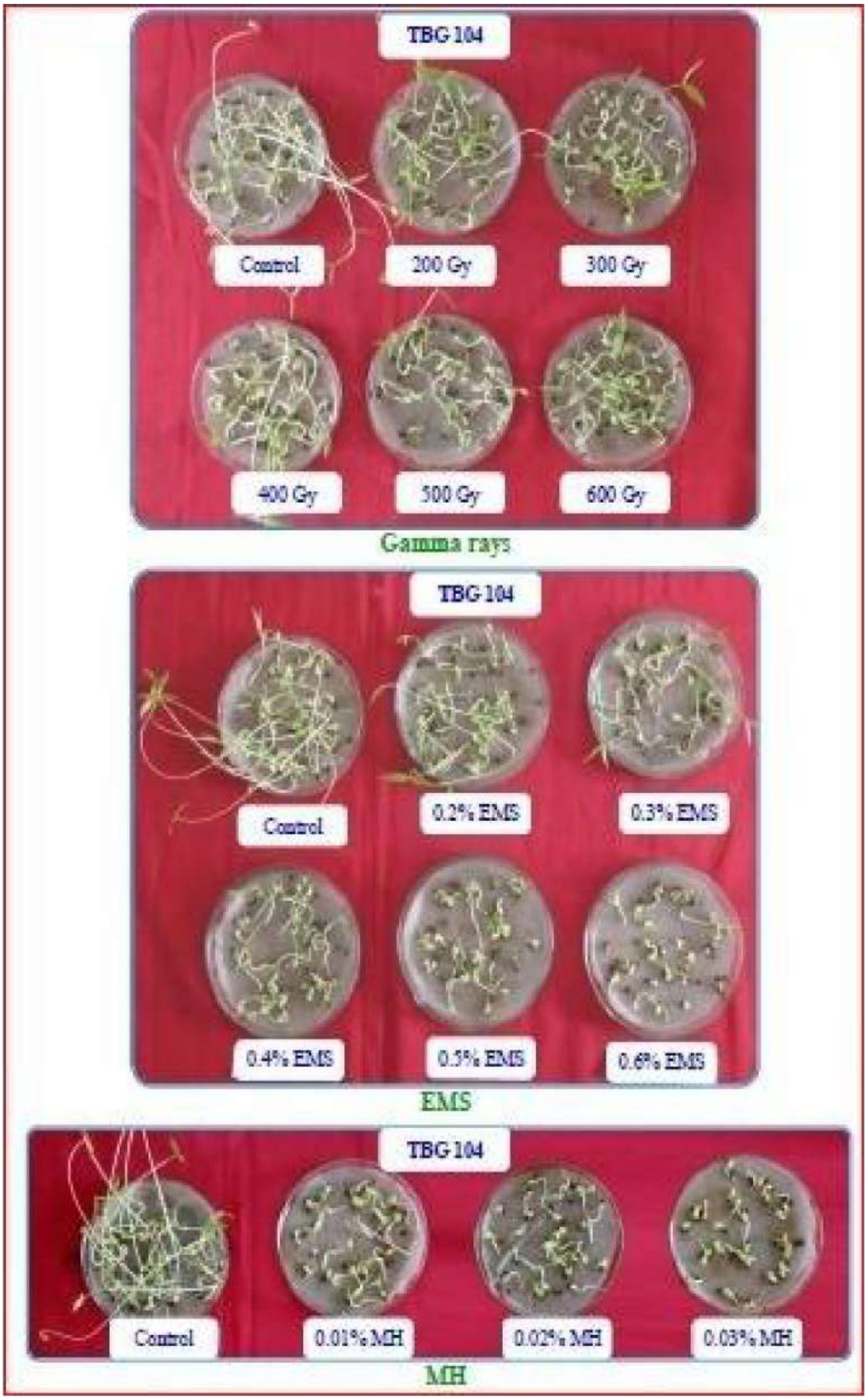

Fig. 2. Effect of mutagens on germination, shoot length and root length in M_1 generation of TBG 104

Table 3. Effect of mutagens on biological parameters in M_1 generation of LBG 752 and TBG 104 under *in-vitro* condition

Treatments	LBG752			TBG104		
	Seed germination (%)	Shoot length (cm)	Root length (cm)	Seed germination (%)	Shoot length (cm)	Root length (cm)
Control	98.33	16.71	4.52	99.33	15.87	4.54
200 Gy	86.67*	13.57*	3.77	97.67	11.52*	3.77
300 Gy	74.67*	12.80*	3.53	89.00*	11.20*	3.58
400 Gy	63.00*	11.77*	3.47	74.33*	8.44*	3.35
500 Gy	52.33*	10.25*	2.85*	55.67*	8.06*	3.13*
600 Gy	38.67*	8.71*	1.98*	45.33*	7.74*	2.81*
Mean	**68.94**	**12.30**	**3.35**	**76.88**	**10.47**	**3.53**
Ethyl methane sulphonate (EMS)						
Control	98.33	16.71	4.52	99.33	15.87	4.54
0.2%	81.67*	11.67*	3.15*	96.67	8.35*	2.93*
0.3%	69.00*	6.50*	2.92*	89.33*	7.82*	2.55*
0.4%	50.67*	5.33*	1.73*	76.00*	6.23*	1.13*
0.5%	37.67*	3.69*	0.91*	57.33*	2.32*	0.88*
0.6%	23.33*	2.87*	0.29*	42.33*	1.58*	0.41*
Mean	**60.11**	**7.80**	**2.25**	**76.83**	**7.03**	**2.07**
Maleic Hydrazide (MH)						
Control	98.33	16.71	4.52	99.33	15.87	4.54
0.01%	72.67*	3.09*	1.24*	68.00*	2.67*	1.23*
0.02%	46.33*	2.17*	1.18*	59.33*	1.63*	1.09*
0.03%	18.00*	0.93*	1.10*	46.33*	1.11*	0.99*
Mean	**58.83**	**5.73**	**2.01**	**68.24**	**5.32**	**1.96**
	SE(m): 1.64 CD(@ 5%): 4.74	SE(m): 1.01 CD(@ 5 %): 2.92	SE(m): 0.37 CD(@ 5 %): 1.07	SE(m): 1.84 CD(@ 5 %): 5.34	SE(m): 0.74 CD(@ 5 %): 2.14	SE(m): 0.48 CD(@ 5 %): 1.38

* Significant decrease than control at P=0.05

Table 6. Mean of growth related traits and pollen fertility in M_1 generation of LBG 752 and TBG 104 under field condition

Treatments	LBG 752				TBG 104			
	Seedling emergence (%)	Seedling survival (%)	Seedling height (cm)	Pollen fertility (%)	Seedling emergence (%)	Seedling survival (%)	Seedling height (cm)	Pollen fertility (%)
Gamma rays								
Control	91.87	89.22	21.00	95.13	92.53	88.62	21.73	87.63
200 Gy	78.13*	75.35*	19.54	89.27	85.47	79.87	19.77	84.72
300 Gy	55.47*	53.68*	19.25	70.64*	73.33*	72.31	18.86	83.43
400 Gy	47.33*	45.28*	18.42	67.98*	51.20*	49.87*	18.50*	73.37*
500 Gy	37.47*	36.11*	17.87*	59.36*	44.80*	43.05*	16.61*	69.43*
600 Gy	27.20*	25.19*	16.35*	51.89*	38.40*	36.53*	14.11*	69.25*
Mean	**56.24**	**54.14**	**18.74**	**72.38**	**64.29**	**61.71**	**18.27**	**77.97**
Ethyl methane sulphonate (EMS)								
Control	91.87	89.22	21.00	95.13	92.53	88.62	21.73	87.63
0.2%	68.80*	64.23*	18.31*	63.86*	86.67	83.36	20.91	85.26
0.3%	57.87*	54.98*	16.33*	54.40*	71.73*	67.55*	17.65*	81.79
0.4%	46.27*	42.96*	14.72*	43.51*	57.20*	51.94*	14.99*	76.27
0.5%	31.60*	27.69*	13.67*	37.67*	45.87*	42.26*	14.05*	45.73*
0.6%	19.87*	16.29*	13.07*	25.17*	39.33*	31.12*	10.08*	42.93*
Mean	**51.59**	**49.23**	**16.18**	**44.92**	**65.56**	**60.81**	**16.57**	**69.94**
Maleic Hydrazide (MH)								
Control	91.87	89.22	21.00	95.13	92.53	88.62	21.73	87.63
0.01%	15.60*	13.47*	14.23*	83.08*	13.07*	12.00*	16.53*	76.68
0.02%	13.60*	12.93*	14.10*	53.07*	12.40*	11.73*	12.15*	43.16*
0.03%	11.87*	10.47*	12.46*	47.69*	11.47*	11.07*	11.42*	31.63*
Mean	**33.24**	**35.12**	**15.45**	**52.41**	**32.37**	**30.86**	**15.45**	**59.78**
SE(m)	1.37	1.44	0.89	3.23	3.06	3.21	1.08	4.21
CD(0.05)	3.99	4.19	2.59	9.38	8.9	9.32	3.15	12.24

* Significant decrease than control at P=0.05

Table 7. Mean of yield and yield related traitsin M_1 generation of LBG 752 under field condition

Treatments	Plant height (cm)	Number of primarybranches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Pod length(cm)	Seed fertility(%)	100 seedweight (g)	Seed yieldper plant(g)
Gammarays									
Control	49.73	2.93	20.87	29.73	6.96	4.94	98.96	4.99	6.11
200 Gy	46.03	2.19*	20.27	28.60	6.39*	4.77*	98.50	4.75*	5.91
300 Gy	45.77*	2.16*	19.07	24.27*	5.87*	4.54*	97.92	4.58*	5.54
400 Gy	45.47*	1.97*	16.00*	22.80*	5.74*	4.32*	95.00*	4.25*	4.54*
500 Gy	43.47*	1.87*	15.33*	18.00*	5.54*	4.19*	92.25*	4.17*	4.36*
600 Gy	41.90*	1.80*	13.20*	16.80*	4.87*	4.08*	83.16*	4.08*	4.26*
Mean	**45.78**	**2.15**	**17.46**	**23.37**	**5.90**	**4.47**	**94.30**	**4.47**	**5.12**
Ethyl methane sulphonate (EMS)									
Control	49.73	2.93	20.87	29.73	6.96	4.94	98.96	4.99	6.11
0.2%	47.65	2.73	19.23	24.53*	6.33*	4.53*	96.92	4.60*	4.70*
0.3%	40.07*	2.67	13.73*	17.93*	6.19*	4.43*	93.92*	4.47*	4.28*
0.4%	33.87*	2.13*	13.20*	16.20*	5.72*	4.32*	86.45*	4.35*	3.96*
0.5%	33.80*	2.03*	11.33*	12.80*	5.57*	4.29*	82.13*	4.26*	3.36*
0.6%	32.87*	1.83*	10.80*	9.47*	5.28*	4.23*	79.70*	4.06*	3.12*
Mean	**39.66**	**2.39**	**14.86**	**18.44**	**6.01**	**4.46**	**89.68**	**4.46**	**4.26**
Maleic Hydrazide (MH)									
Control	49.73	2.93	20.87	29.73	6.96	4.94	98.96	4.99	6.11
0.01%	38.73*	2.50	20.10	21.77*	6.93	4.61*	96.54	4.90	6.05
0.02%	34.20*	2.13*	18.47	18.33*	6.77	4.39*	95.51	4.42*	5.69
0.03%	33.43*	1.90*	15.27*	11.13*	6.70*	4.28*	86.89*	4.09*	4.82*
Mean	**39.03**	**2.37**	**18.68**	**20.24**	**6.44**	**4.56**	**94.48**	**4.60**	**5.67**
SE(m)	1.34	0.17	1.22	1.34	0.08	0.03	1.2	0.05	0.2
CD @ 5 %	3.9	0.49	3.56	3.88	0.24	0.1	3.48	0.15	0.57

* Significant decrease than control at P=0.05

Table 4. Analysis of variance for thirteen characters in M_1 generation of LBG 752 under field condition

S. No.	Characters	Mean sum of squares		
		Replications (df: 2)	Treatments (df: 13)	Error (df: 26)
1.	Seedling emergence (%)	11.707	1897.740**	5.659
2.	Seedling survival (%)	22.400	1837.180**	6.218
3.	Seedling height (cm)	2.228	22.134**	2.374
4.	Pollen fertility (%)	12.599	1175.922**	31.240
5.	Plant height (cm)	12.758	108.521**	5.410
6.	Number of primary branches per plant	0.252	0.397**	0.084
7.	Number of clusters per plant	0.542	35.694**	4.494
8.	Number of pods per plant	2.586	113.398**	5.352
9.	Number of seeds per pod	0.017	1.343**	0.020
10.	Pod length (cm)	0.003	0.165**	0.003
11.	Seed fertility (%)	7.434	133.458**	4.297
12.	100-seed weight (g)	0.028	0.274**	0.008
13.	Seed yield per plant (g)	0.098	2.834**	0.116

** Significant at 1% level

Table 5. Analysis of variance for thirteen characters in M_1 generation of TBG 104 under field condition

S. No.	Characters	Mean sum of squares		
		Replications (df: 2)	Treatments (df: 13)	Error (df: 26)
1.	Seedling emergence (%)	35.341	2307.060**	28.137
2.	Seedling survival (%)	6.105	2157.880**	30.820
3.	Seedling height (cm)	22.416	38.626**	3.527
4.	Pollen fertility (%)	89.330	1068.830**	53.172
5.	Plant height (cm)	2.771	26.461**	1.129
6.	Number of primary branches per plant	0.002	0.355**	0.023
7.	Number of clusters per plant	1.460	11.129**	0.388
8.	Number of pods per plant	1.930	57.237**	3.250
9.	Number of seeds per pod	0.105	0.187**	0.032
10.	Pod length (cm)	0.005	0.190**	0.006
11.	Seed fertility (%)	1.970	31.142**	1.668
12.	100-seed weight (g)	0.012	0.192**	0.008
13.	Seed yield per plant (g)	0.009	1.337**	0.008

** Significant at 1% level

Table 8. Mean of yield and yield related traits in M_1 generation of TBG 104 under field condition

Treatments	Plant height (cm)	Number of primarybranches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Pod length(cm)	Seed fertility(%)	100 seedweight (g)	Seed yieldper plant (g)
Gammarays									
Control	29.07	2.70	14.97	21.13	6.37	4.93	98.53	5.18	5.82
200 Gy	27.77	2.60	14.73	20.87	6.15	4.88	97.46	5.09	5.10*
300 Gy	24.50*	2.57	13.70*	18.50	6.00*	4.78*	96.84	4.89*	4.81*
400 Gy	23.13*	2.23*	12.27*	16.17*	5.97*	4.66*	96.52	4.84*	4.43*
500 Gy	22.13*	2.00*	11.00*	14.73*	5.80*	4.57*	93.50*	4.58*	3.71*
600 Gy	21.60*	1.73*	10.77*	11.27*	5.53*	4.39*	90.93*	4.44*	3.43*
Mean	**24.70**	**2.31**	**12.91**	**17.11***	**5.97**	**4.70**	**95.63**	**4.84**	**4.55**
Ethyl methane sulphonate (EMS)									
Control	29.07	2.70	14.97	21.13	6.37	4.93	98.53	5.18	5.82
0.2%	27.03*	2.53	14.07	19.90	6.30	4.72*	97.36	5.01*	5.12*
0.3%	24.47*	2.37*	12.47*	16.50*	6.13	4.59*	96.02*	4.88*	4.56*
0.4%	22.60*	2.13*	12.37*	14.67*	6.06*	4.49*	93.38*	4.73*	4.33*
0.5%	22.07*	2.00*	11.20*	9.67*	5.93*	4.37*	89.57*	4.52*	4.19*
0.6%	18.80*	1.67*	9.23*	6.13*	5.60*	4.28*	89.37*	4.38*	3.86*
Mean	**24.01**	**2.23**	**12.38**	**14.67**	**6.07**	**4.56**	**94.04**	**4.78**	**4.65**
Maleic Hydrazide (MH)									
Control	29.07	2.70	14.97	21.13	6.37	4.93	98.53	5.18	5.82
0.01%	24.44*	2.67	14.30	17.93*	6.33	4.87	98.47	5.11	5.33*
0.02%	21.53*	2.20*	12.00*	14.93*	6.11	4.23*	97.39	4.90*	4.97*
0.03%	19.53*	1.93*	8.93*	12.20*	6.00*	4.17*	93.02*	4.84*	4.89*
Mean	**23.64**	**2.38**	**12.55**	**16.55**	**6.20**	**4.55**	**96.85**	**5.01**	**5.25**
SE(m)	0.61	0.09	0.36	1.04	0.1	0.04	0.75	0.05	0.05
CD @ 5 %	1.78	0.25	1.05	3.03	0.3	0.13	2.17	0.15	0.15

* Significant decrease than control at P= 0.05

percent, 60.81 percent and 30.86 percent, respectively. Reduction in seedling emergence percentage was high under field condition compared to seed germination percentage under *in-vitro* condition, which might be due to the fact that various macro and micro environmental factors also control the seedling emergence apart from other genetical and physiological and biochemical factors. Based on reduction in mean values of all the characters, it was observed that the LBG 752 was found to be more sensitive than TBG 104 to gamma rays, EMS and MH treatments. The variety TBG 104 tolerated better than the LBG 752 at varied concentrations of the different mutagenic treatments. The differential sensitivity of genotypes may be attributed to their metabolic processes being affected in different manner either by mutagen uptake or degradation and or sites of action in the embryo (Levy and Ashri, 1973).

CONCLUSION

This study on effect of various mutagens on two blackgram varieties *viz.,* LBG 752 and TBG 104 in M_1 revealed that among all the treatments, MH treatment resulted in drastic reduction in seed germination percentage, shoot length, root length, seed emergence percentage, seedling survival, seedling height and pollen fertility followed by EMS and gamma rays treatments in both the varieties. Thus, gamma ray treatments are highly effective in both the varieties for modifying the majority of the traits in the crop with less biological damage followed by EMS and MH treatments. Higher doses of all the mutagens caused considerable reduction in all the traits studied. It was also noticed that the reduction in all these characters with increasing dose/concentration of mutagens was conspicuous in LBG 752 than TBG 104 indicating more sensitivity of LBG 752 to mutagen treatment than TBG 104. The information on M_1 parameters may help in the initial rejection of less important mutagenized populations which may save time and efforts in further mutation breeding programme.

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OPTIMIZATION OF CONCENTRATION AND DURATION OF SEED NUTRIPRIMING WITH IRON SULPHATE FOR SEED QUALITY ENHANCEMENT IN BLACKGRAM

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ABSTRACT

The investigation was carried out to optimize the concentration and duration of nutripriming withiron sulphate for seed quality enhancement in blackgram variety, Tulasi. The experiment was conducted during 2019-20 using Factorial Completely Randomized Design(FCRD) and replicated four times. Seeds were subjected to nutripriming with various concentrations (0, 0.01%, 0.05%, 0.1% and 0.5%) of iron sulphate for different durations (0, 2, 4, 6 and 8 h). Primed as well as unprimed seed of blackgram were tested for germination and seedling growth using between paper method. It is evidentthat nutripriming with iron sulphatewas effective in improving the seed quality of Tulasi.Among all the concentrations, 0.1% iron sulphate was found effective in recording highest germination (%), seedling length (cm) and seedling vigour index. Irrespective of concentration, priming for 6h showed maximum improvement for seed quality parameters. Nutripriming with 0.05% iron sulphate for 6 h resulted in better enhancement of germination and seedling quality parameters in blackgram.

Keywords: Blackgram, Germination, Nutripriming, Seedling quality, Iron sulphate

INTRODUCTION

Blackgram is an important pulse crop and rich source of protein.Being a leguminous crop, it prevents soil erosion and restores the soil fertility by fixing atmospheric nitrogen. India is the largest producer as well as consumer of blackgram.It is mainly cultivated in rice fallows by utilizing the residual soil moisture. The low productivity of blackgram is due toits cultivation in marginal and sub-marginal lands with poor management practices. To exploit the full genetic potentiality, it is essential to adopt improved crop management technology.

Micronutrient deficiencies are now commonly observed in fully grown cereals, oilseeds, pulses and vegetable crops. Interpretation of soil and plant samples has indicated that 12% of soils in India are seemingly defective in Fe (Singh, 2008). Iron is not easily available in neutral to alkaline soils. Although abundant in most well-aerated soils, the

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biological activity of iron is low because it primarily forms highly insoluble ferric compounds at neutral pH levels.

Insufficient iron uptake by the plants causes retarded growth, interveinal chlorosis leading to reduction in yield and nutritional quality of the produce.Sufficient iron levels in food crops are critical to combat iron deficiency-induced anemia, one of the major nutritional disorders in human beings worldwide.

Seed priming with micronutrients (nutri priming) is a technique where seeds are soaked in micronutrient solution instead of water at a particular concentration and priming duration. It is a very promising, viable and low cost alternative to the conventional soil and/or foliar application of micro-nutrients. Availability of sufficient nutrients in the seed helps in better germination and early seedling establishment. It provides nutrition until root begins to absorb nutrients from soil (Muhammed *et al.,* 2015). Hence, the investigation was carried out to know the optimum concentration of iron sulphate and duration of seed priming for improving germinationpercent and seedling vigour in blackgram variety 'Tulasi'.

MATERIAL AND METHODS

This laboratory experiment was conducted in the Department of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur, ANGRAU during 2019-20. The experiment was conducted in Factorial Completely Randomized Design (FCRD) and replicated four times.The blackgram variety'Tulasi' (LBG-787) seed was soaked in either water (hydropriming - without iron sulphate) or various concentrations (0,0.01%, 0.05%, 0.1% and 0.5 %) of iron sulphate solution for different durations (0 h,2 h, 4 h, 6 h and 8 h) by maintaining the seed to solution ratio of 1:2 (w/v). After priming, seeds were washed thoroughly with distilled water and dried to safe moisture content (9%) under shade. Germination test was conducted by between paper method using 100 seeds from each replication of each treatment. After a test period of seven days, observations were recorded on the following parameters as per the details mentioned below:

Germination (%): The normal seedlings were counted and expressed as germination (%) as per the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seed sown}} \times 100$$

Seedling Length (cm): The total distance from the tip of primary leaf to root tip of ten randomly chosen seedlings from each replication of treatments was measured with a scale and their mean was expressed as seedling length in centimeters.

Seedling Vigor Index: It was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and was expressed in whole number.

Seedling Vigor Index = Germination (%) × [Mean root length + mean shoot length (cm)]

The data were analyzed using SPSS (version 16.0) software after subjecting the obtained data to appropriate transformations. The differences among the means of concentrations of micronutrient and duration of priming were compared by using Duncan's multiple range test (1955) at 5% level of probability.

RESULTS AND DISCUSSION

Seed priming exhibited a beneficial effect on germination and seedling growth of blackgram. Analysis of variance (Table1) of data revealed that nutripriming with iron sulphate at different concentrations, various durations and their interaction showed highly significant variation for all seed quality parameters *viz.*, germination (%), seedling length (cm) and seedling vigour index.The impact of hydropriming in improving the seed quality parameters was noticed to be lesser than that due to nutripriming with iron sulphate.

There was a progressive increase in mean germination from 83.90 % (0%) to 87.45% (0.05%) upon nutripriming with iron sulphate in blackgram genotype, Tulasi (Table2). Further increase in concentration up to 0.5% decreased the mean germination to 85.15%. The increment in mean germination upon seed priming with 0.05% iron sulphate over control was 4.23%. (Fig.1).Duration of priming had significant effect on germination in blackgram genotype, Tulasi. Nutripriming with iron sulphate showed highest mean germination (88.25%) with 6 h of priming which was observed to be the most effective duration. Further increase in duration of Nutripriming up to 8 h (85.90%) caused a significant decline in mean germination (Table 2). The percent increase in mean germination upon seed priming for 6 h over control was 6.52% (Fig.2). Highest germination (91.25%) was recorded upon seed priming with 0.05% iron sulphate for 6 h. The lowest germination (82.75%) was obtained with unprimed seed. The overall mean germination was 85.36% (Table2). Wei *et al.* (2013) found a significant decline in germination with increase in concentration of iron sulphate beyond 0.25g L^{-1} for seed fortification in germinated brown rice. Niu *et al.* (2019) testified that seed priming with iron at 0.6% for 24 h significantly improved the germination in contrast to unprimed seeds in *Gentiana macrophylla.*

Seedling length was gradually and significantly improved with increase in concentration of iron sulphate for seed priming from 0% (24.07 cm) to 0.05% (27.11 cm) (Table 2). The percent improvement in seedling length with 0.05% iron sulphate over control was 12.6% (Fig.1). Duration of priming considerably improved the mean seedling length of blackgram genotype, Tulasi, from 21.59 cm (0 h) to 28.51 cm (6 h) (Table 2). Priming for 6 h showed 32.1% improvement in seedling length over control (Fig. 2). Nutripriming with iron sulphate at 0.05% for 6 h recorded maximum seedling length (31.68 cm). Minimum seedling length (21.38 cm) was recorded with unprimed seed with an overall mean seedling length of 25.52 cm (Table 2).

Table 1. Seed quality traits in blackgram genotype, Tulasi as effected by seed priming with different concentrations of iron sulphate for various durations

Source	Germination (%)	Seedling length (cm)	Seedling vigor index
Concentration	25.53**	25.06**	349682.90**
Duration	55.49**	137.55**	1500321.37**
Duration × Concentration	2.33**	3.37**	40456.31**
Error	0.81	0.84	6817.30

** Significant difference at 1% probability level

Table 2. Effect of seed priming with different concentrations of iron sulphate and durations on seed quality parameters of blackgram genotype, Tulasi

Duration (h)	Germination (%)						Seedling length (cm)						Seedling vigour index					
	Concentration of iron sulphate(%)						Concentration of iron sulphate(%)						Concentration of iron sulphate(%)					
	0#	0.01	0.05	0.1	0.5	Mean	0#	0.01	0.05	0.1	0.5	Mean	0#	0.01	0.05	0.1	0.5	Mean
0	82.75 (65.44)	82.75 (65.44)	83.00 (65.63)	83.00 (65.63)	82.75 (65.44)	**82.85^{D} (65.51)***	21.38	21.51	21.58	21.80	21.68	**21.59^{D}**	1770	1780	1792	1809	1794	**1789^{D}**
2	83.75 (66.21)	83.00 (65.63)	86.75 (68.66)	84.00 (66.41)	84.00 (66.40)	**84.30^{C} (66.66)**	23.60	24.91	25.08	24.02	24.79	**24.48^{C}**	1976	2067	2176	2017	2082	**2064^{C}**
4	84.00 (66.40)	84.75 (66.99)	87.50 (69.29)	85.75 (67.80)	85.50 (67.59)	**85.50^{B} (67.62)**	24.58	25.77	28.31	26.17	26.84	**26.33^{B}**	2065	2183	2476	2244	2295	**2253^{B}**
6	85.75 (67.80)	87.25 (69.06)	91.25 (72.78)	88.75 (70.39)	88.25 (69.94)	**88.25^{A} (69.99)**	25.93	26.88	31.68	29.29	28.77	**28.51^{A}**	2223	2345	2891	2599	2539	**2519^{A}**
8	83.25 (65.82)	85.75 (67.82)	88.75 (70.39)	86.50 (68.45)	85.25 (67.40)	**85.90^{B} (67.98)**	24.07	25.89	28.90	27.14	26.70	**26.69^{B}**	2068	2219	2565	2349	2276	**2295^{B}**
Mean	**83.90^{d} (66.34)**	**84.70^{c} (66.99)**	**87.45^{a} (69.35)**	**85.60^{b} (67.74)**	**85.15^{bc} (67.32)**	**85.36 (67.55)**	**24.07_{d}**	**24.99^{c}**	**27.11^{a}**	**25.68_{b}**	**25.75_{b}**	**25.52**	**2020_{d}**	**2119^{c}**	**2380^{a}**	**2204^{b}**	**2197^{b}**	**2184**
	D		C		D × C		D		C		D × C		D		C		D × C	
S Em ±	0.20		0.20		0.45		0.21		0.21		0.46		18.46		18.46		41.28	
CD (5%)	0.57		0.57		1.27		0.58		0.58		1.30		52.12		52.12		116.54	
CV (%)	1.33						3.60						3.78					

Hydropriming (seed priming with distilled water without any micronutrient); *Values in the parenthesis indicate arc-sine transformed values; The values in the same column with the same alphabet are not significantly different as per DMRT ($P < 0.05$)

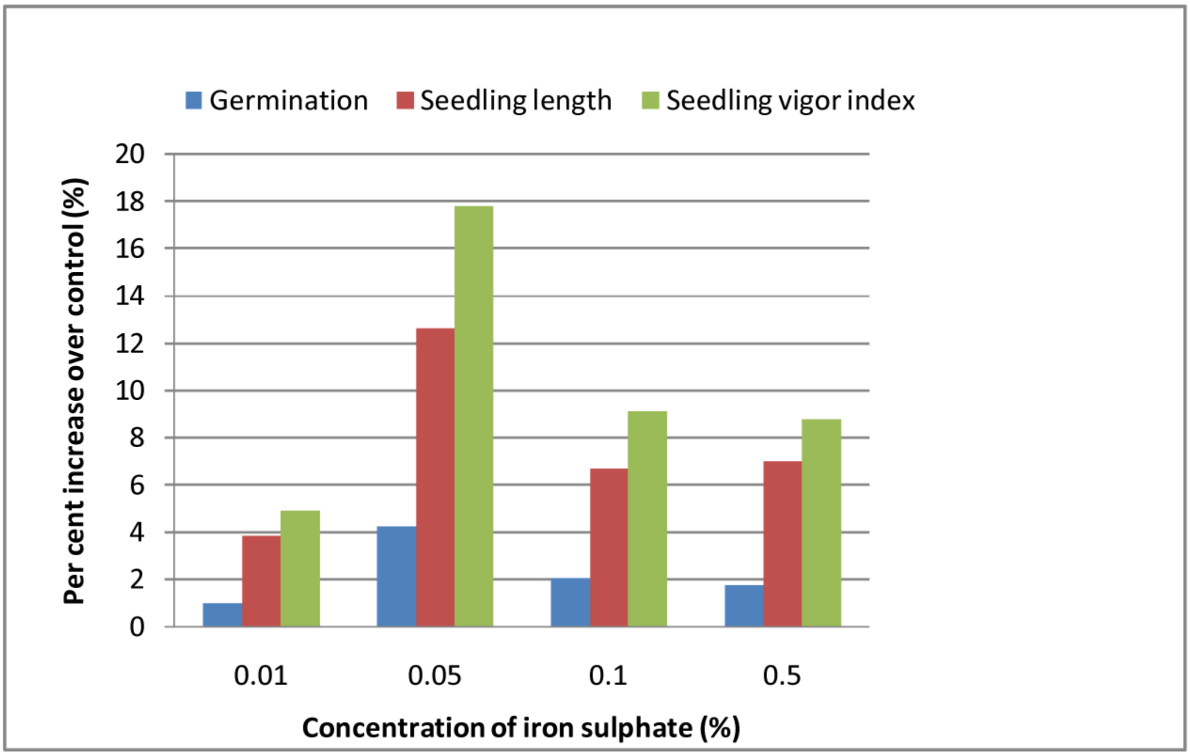

Fig.1. **Percent increase over control on seedling parameters after seed priming with iron sulphate for various concentrations in blackgram genotype, Tulasi**

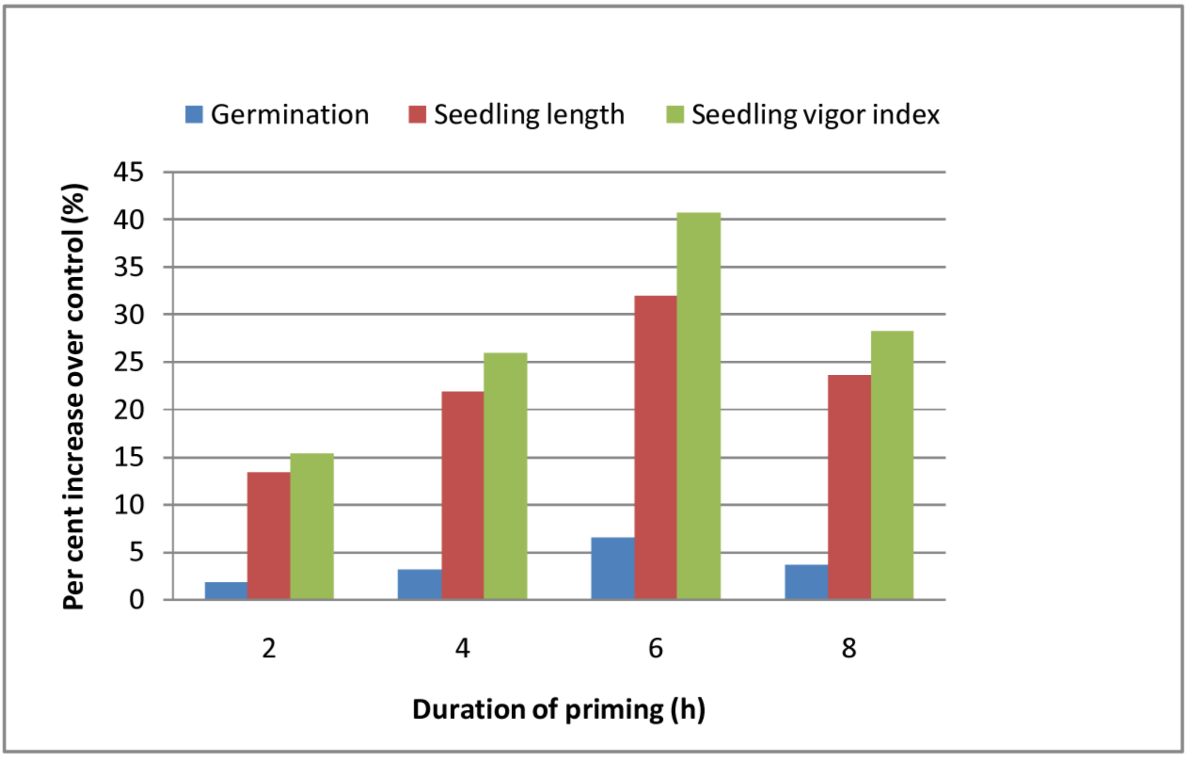

Fig. 2. **Percent increase over control on seedling parameters after seed priming with iron sulphate for various durations in blackgram genotype, Tulasi**

Nutripriming with iron sulphate increased the mean seedling vigour index from 2020 (0%) to 2380 (0.05%) and decreased with further increase in concentration up to 0.5% (2197) (Table 2). The increased percent in mean seedling vigour index at 0.05% iron sulphate was 17.82% in comparision to control (Fig.1). Duration of nutripriming with iron sulphate enhanced the mean seedling vigour index from 1789 (0 h) to 2519 (6 h) (Table 2). The increasedpercentin mean seedling vigour index with 6 h of priming over control was 40.8% (Fig.2).Maximum seedling vigour index (2891) was recorded upon nutripriming with iron sulphate at 0.05% for 6 h,whereas, least seedling vigour index (1770) was recorded with unprimed seed. The grand mean seedling vigour index was 2184 (Table 2). Increase in seed vigor index upon nutriprimingmight be due to significant increase in germination and seedling length. Mirshekari (2010) recorded maximum seedling vigour index after seed priming with 1.5% iron sulphate for 12 h and observed that further increase in concentration had negative impact in dill.

Enhancement of seed quality parameters withseed priming with iron sulphate might be due to its involvement in redox enzymes required for the synthesis of chlorophyll (Mondal and Bose, 2019). Excess of iron concentration leads to reduced seedling growth as it causes abnormalities during cell division as reported by Reis *et al.* (2018).

CONCLUSION

It was recorded that seed priming with 0.05% iron sulphate for 6h caused maximum improvement in germination and seedling quality parameters of blackgram genotype, Tulasi.

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INFLUENCE OF CHEMICALS AND PLANT GROWTH REGULATORS ON PLANT GROWTH AND YIELD OF AFRICAN MARIGOLD DURING SUMMER

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ABSTRACT

The two-year research was conducted during 2017 and 2018 to study the influence of certain chemicals like calcium nitrate, potassium nitrate and plant growth regulators *viz.,* GA_3, salicylic acid and homobrassinolide against heat stress tolerance during summer on plant growth and flower yield of African marigold cv. Bidhan Marigold-2. Salicylic acid spray @ 200 ppm once at 30 days after transplanting (DAT) recorded maximum values in terms of flower diameter (4.35 cm), ten flower weight (44.57 g), flower yield (158.39 q ha^{-1}) which was followed by 2% potassium nitrate spray with flower yield of 141.52 q ha^{-1} whereas untreated plots (control) recorded the lowest values in all the growth and yield paramters

Key words: Calcium nitrate; Gibberllic acid; Homobrassinolide; Marigold; Potassium nitrate; Salicylic acid

INTRODUCTION

Among the commercial loose flowers cultivated in Andhra Pradesh, the area under marigold cultivation is in an increasing trend for the past few years due to its gaining commercial usage in the industrial area for extraction of natural food colour, feed purpose as well as in open market for decorations and retail sale. The yield of marigold during summer is severly affected due to high temperature induced stress in plants resulting in early senescence thereby reducing the flower yield drastically. Plant growth regulating chemicals play an important role in overcoming the factors limiting the yield and quality of flowers during heat stress by changing plant morphology and physiology. The response exhibited by plants to these chemicals varies with species, cultivars and seasons. Exogenous application of GA_3 reversed the inhibitory effect of salt, oxidative and heat stresses on seed germination and seedling establishment in Arabidopsis. Further, an increase in salicylic acid biosynthesis suggests that gibberllins are implicated in plant responses to abiotic stress by modulating salicylic acid levels (Alonso-Ramirez *et al.,* 2009). Improvement in the levels of stress in plants is noticed by salicylic acid application thereby increasing the pro-

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production and restriction in the formation of ethylene under heat stress conditions. Application of calcium nitrate under heat stress conditions increased the photochemical efficiency of photosystem-II (PS-II) over control. Calcium nitrate protected the subunits of PS-II reaction centers from photo-inhibition by reducing the generation of reactive oxygen species, thus, higher non-photochemical quenching and lower levels of membrane damage was observed (Sha Yang *et al.,* 2015). Increase in the rate of photosynthetic efficiency of plants and reduction in chloroplast dehydration under heat stress conditions was recorded by exogenous application of potassium nitrate. Exogenous application of potassium. Dhaubhadel *et al.* (2002) noticed a dominant role of brassinosteroids in protecting the translational machinery and heat-shock protein synthesis during thermal stress. Brassinosteroids increased the plant resistance to heat stress by induction of 3â-hydroxy steroid dehydrogenase (EC 1.1.1.145), a key enzyme of steroid metabolism in the leaves of potato.

African marigold cultivar Bidhan Marigold-2 is reported to be suitable for year round cultivation under west Bengal conditions of India. Hence, an experiment was designed to find out the influence of various chemicals and plant growth regulators on plant growth and flower yield of Bidhan Marigold-2 during summer in coastal region of Andhra Pradesh and find the suitability of this cultivar for summer cultivation in this region.

MATERIALS AND METHODS

The experimental site was located at the Horticultural Research Station, Venkataraman-nagudem, West Godavari district of Andhra Pradesh geographically situated at 16°83' N latitude and 81°5' E longitude with an altitude of 34 m (112 feet) above the mean sea level. This zone experiences hot and humid summer, mild winter and an average annual rainfall of 900 mm. the experiment was carried out in summner months during 2017 and 2018. The marigold variety selected for is orange coloured Bidhan Marigold-2 which is a selection from cultivar 'Siracole'. The experiment was laid out in a Randomized Block Design replicated four times with a plot size of 2.8 m x 3.0 m. The experiment consists of six treatments *viz*., gibberillic acid (GA_3) @ 150 ppm; salicylic acid (SA) @ 200 ppm; calcium nitrate ($Ca\ (NO_3)_2$) @ 2%; potassium nitrate (KNO_3) @ 2%; 28 homobrassinolide (28 HBL) @ 1 ppm and control with no treatment (water spray alone).

Solution of 150 ppm GA_3 was prepared by dissolving 150 mg of GA_3 in one litre of distilled water; 200 ppm of SA by dissolving 200 mg of SA in one litre of distilled water; calcium nitrate solution of 2% concentration by dissolving 20 g of $Ca\ (NO_3)_2$ in one litre of distilled water; Potassium nitrate solution of 2% concentration by dissolving 20 g of KNO_3 in one litre of distilled water. Similarly, 28-Homobrassinolide solution of one ppm concentration was prepared by dissolving 1 mL of "Double" a commercial formulation of 28-Homobrassinolide in one litre of distilled water. Freshly prepared chemical solutions of desired concentration were sprayed once at 30 days after planting as per the treatment. Spraying was carried out during early morning hours until the spray solution was run off from the plants by using a manual sprayer.

Observations on vegetative growth, flowering and yield parameters were recorded at 150 days after transplanting for ten random plants. Fresh leaf biomass of marigold at maturity was collected and dried in hot air oven through gravimetric method for obtaining dry matter. Specific leaf weight was then calculated by dividing leaf dry weight with leaf area and expressed in mg cm^{-2}. Relative water content (RWC) was estimated as per the procedure explained by Weatherely and Barrs (1962). Moisture content in flower petals and physiological loss in weight (PLW) was calculated as per Ranganna (1999). Total carotenoid content in marigold flower petals was estimated as per Bhaskarachary *et al.* (1995). The peroxidase activity in leaves was estimated as per Perur (1962). Catalase activity in leaves was estimated as per Gopalachari (1963) and membrane integrity of the cell in leaves as per Leopold *et al.* (1981).

RESULTS AND DISCUSSION

Effect of pre harvest sprays on vegetative parameters

Application of salicylic acid @ 200 ppm recorded the maximum plant height (108.21 cm), more number of primary (13.88) and secondary branches (62.63), highest internodal length (4.90 cm), more plant spread (59.40 cm in E-W and 58.18 cm in N-S directions), leaf area (131.49 dm^2), stem diameter (1.58 cm), specific leaf weight of 16.11 mg cm^{-2}, plant fresh biomass (1986.04 g) and dry matter $plant^{-1}$ (375.43 g) which was followed by 2% potassium nitrate and 28 Homobrassinolide @ 1 ppm sprays.

Salicyclic acid is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plants such as growth, photosynthesis, nitrate metabolism, ethylene production, heat production and flowering (Hayat *et al.,* 2010). It also regulates the plant growth and cell division *via* other hormones like auxin, cytokinin, gibberellin and ABA. The maximum plant height with salicylic acid might be due to prevention of auxin and cytokinin loss in plants thereby enhancing cell division, cell enlargement and tissues formation resulting in increasing the plant height and internodal length. Salicylic acid maintains the chlorophyll content at proper level, thus, helping the plants to grow well and develop. These findings are in conformity with Pacheco *et al.* (2013) in marigold and Mehdi *et al.* (2015) in rose. Improvement in primary and secondary branches production might be due to the hyper elongation of internodal length which caused an extension in plant height in addition to increase in nodal count on main axis which consequently increased number of dormant buds from where the primary branches were originated with the application of salicylic acid (Mittler, 2002). The above results are in conformity with Kumar *et al.* (2012) in rose. Production of more number of branches and leaves facilitated more photosynthetic area and metabolic activities resulting in better transport and utilization of the photosynthetic metabolites thereby increasing plant spread in both E-W and N-S directions. Similar results were earlier reported by Hussein *et al.* (2007 a) in maize.

Application of salicylic acid might have maintained the photosynthetic rate during heat stress similar to that under normal conditions thus ensuring the highest leaf area of the plant better than that of other treatments. Similar results were obtained by Gad *et al.* (2016) in ixora. Prolonged growth period due to salicylic acid spray allowed the plants for better utilization of nutrients and water present in the soil efficiently thus improving the photosynthesis and vegetative growth of the plants. Increased number of branches and leaves might have facilitated more photosynthetic area and metabolic activities resulting in better transport and utilization of the photosynthetic metabolites resulting in increased stem diameter. Similar results were found by Zarghami *et al.* (2014) in petunia. The increase in the specific leaf weight, fresh biomass of the plant and dry matter plant^{-1} with the application of salicylic acid might be attributed to the increase in leaf area which further facilitated an increase in leaf dry weight due to increased photosynthetic activity of the plant. Mehdi *et al.* (2015) in rose reported results in line with this study (Table 1).

Plants sprayed with 2% calcium nitrate have recorded the highest relative water content of 98.31% followed by salicylic acid @ 200 ppm spray (97.33%). Calcium in cellular solution maintains normal membrane function and ensures the selective permeability of the membrane apart from regulating guard-cell turgor and stomatal aperture (Mansfield *et al.,* 1990; Webb *et al.,* 1996). External calcium may interfere with cellular calcium and affect osmotic adjustment of cells under stress conditions to maintain the normal conditions. Similar result of increase in relative water content with calcium application in Kentucky bluegrass under heat stress condition was reported by Yiwei Jiang and Bingru Huang (2001), where, calcium sprayed plants showed on par relative water content values compared to plants grown without heat stress implying calcium spray effectively protects the plants from heat stress.

Effect of pre harvest sprays on flower parameters

Plants sprayed with 2% calcium nitrate had taken maximum days for first flower bud appearance (45.93 days) and 50% flowering (62.43 days) followed by salicylic acid @ 200 ppm which might be due to the well nourishment obtained with adequate nitrogen in the form of nitrate along with calcium that led to higher metabolic activity in leaves and synthesis of carbohydrates thus helping the plants to continue in the vegetative phase for longer time leading to the delayed flower bud initiation. Calcium involved signal transduction pathway has been found to help plants to adapt to stress such as high temperature by evoking gene expression and activating a series of biochemical responses. Calcium improvement of photosynthesis is related to enhanced activity of antioxidant enzymes to alleviate reactive oxygen species (ROS) accumulation. Decrease in intracellular ROS contributes to the protection of PSII proteins to alleviate the photo-damage under light and salt stress because high ROS levels could suppress the synthesis of the D1 protein and almost other proteins. It can be speculated that exogenous calcium may play a role in protecting the subunits of PSII reaction centres from photo-inhibition by reducing the generation of ROS (Sha Yang *et al.,* 2015). Additionally, it has been reported that the calcium could stimulate the rate of electron transports on the acceptor side in PSII (Semin *et al.,* 1998); thus, there is some other way for calcium to protect PSII reaction centres, especially synthesis of PSII reaction centre proteins de novo. These results are in conformity with

Saidulu (2013) in marigold. Control plants had taken lowest number of days (34.80 days) for first flower appearance. It might be due to the fact that heat stress reduces the photosynthetic efficiency of plants by denaturing thylakoid membranes and chloroplasts, increases water loss and nutrients eventually leading to early senescence which in turn induces early flower initiation. The minimum days taken for 50% flowering in control (44.48 days) is attributed to the early initiation of flowering due to early onset of senescence under heat stress compared to the other treatments.

Regarding duration of flowering plants sprayed with salicylic acid @ 200 ppm recorded the maximum flowering duration of 85.38 days whereas, minimum of 62.58 days was recorded in control. The flower inducing domain of salicylic acid makes it an important phytohormone that can enhance flowering in a variety of ornamental plants (Hayat *et al.,* 2010). Genetic studies pointed out to salicylic acid as a regulator of flowering time that interacts with both the photoperiod-dependent and autonomous pathways (Martinez *et al.,* 2004). Results in line with this study were reported by Pacheco *et al.* (2013) in marigold. Slight variation had been witnessed in flower diameter and the data ranged from 3.5 cm to 4.5 cm. Plants sprayed with salicylic acid @ 200 ppm recorded maximum flower diameter of 4.35 cm by forming sink in such a position where it accumulates and draws the available photosynthates efficiently to this site. Results in line with this study are also recorded by Kumar *et al.* (2012) in rose. The maximum flower receptacle length of 1.98 cm obtained with salicylic acid @ 200 ppm spray might be due to the controlled loss of auxin and cytokinin in plants by salicylic acid enhancing cell division and enlargement of cells and tissues (Hayat *et al.*, 2010). These findings are in conformity with Pacheco *et al.* (2013) in marigold and Mehdi *et al.* (2015) in rose.

The maximum moisture content of 87.56 % in flowers was recorded with 2% calcium nitrate because calcium might have improved the cell wall strength and delayed the increase in membrane permeability resulting in the improved water status in petals. This could also be due to improvement in the flower water status and indicate that a possible mode of calcium action is *via* maintenance of membrane integrity and function (Torre *et al.,* 1999). Similar results were reported by Torre *et al.* (1999) in rose and Saidulu (2013) in marigold. Regarding shelf life of flowers at room temperature, maximum shelf life of 4.83 days was obtained with salicylic acid @ 200 ppm spray followed by 2% calcium nitrate (4.64 days). Enhanced shelf life of flowers with salicylic acid might be due to the inhibition of ethylene bio-synthesis and ABA antagonized by salicylic acid thus leading to delayed senescence (Hayat *et al.,* 2007). Salicylic acid has the ability to increase the vase- life of flowers and delay senescence by regulating plant water content and increasing the scavenging capacity of cells. It also participates in signal regulation of gene expression in the course of leaf and petal senescence (Hussein *et al.,* 2007 b) of gladiolus. Similar results were earlier reported by Abdoalla *et al.* (2012) in cut gladiolus cv. 'Wing's Sensation'.

Pre harvest sprays had significantly influenced the physiological loss of weight (PLW) of Bidhan Marigold -2 flowers at different days after harvest (DAH) during storage. Application of 2% calcium nitrate spray recorded lowest PLW with 4.15%, 6.61%, 10.16%, 17.22% and 30.96% from one DAH to five DAH, respectively because of the fact that calcium plays an important role in providing stability and mechanical strength to cell walls (Poovaiah *et al.,* 1988). The increased moisture content in the calcium nitrate treated flowers might be due to the element calcium, which might have improved the cell wall strength and delayed the increase in membrane permeability resulting in the improved petals water status. The stomatal closure promoted by ABA involves calcium and sphingosine-1-phosphate (Melotto *et al.,* 2006) which might also led to low PLW. The increased calcium concentrations in the petals might have lowered membrane permeability leading to better membrane functionality, which maintains the normal cellular functions for a longer period. Due to this reason the pre-harvest spray of calcium nitrate treated flowers recorded the minimum PLW and remained turgid for a longer time and with increased membrane integrity, the flower petals recorded more turgid weight. In this experiment the increase in moisture content with the application of calcium nitrate which eventually recorded lower PLW and the highest RWC was witnessed. Normal membrane function and selective permeability of the membrane due to calcium nitrate spray might have resulted in the minimum PLW and remained turgid for a longer time without losing moisture.Similar results were earlier reported by Hayat *et al.* (2008) in tomato. (Table 2).

Effect of pre harvest sprays on quality parameters

Pre harvest spray of salicylic acid @ 200 ppm recorded maximum carotenoid content of 1.56 g kg^{-1} petals and lowest ethylene production of 1.07 ppm h^{-1} (Table 3). This might be due to activation in the synthesis of carotenoids and xanthophylls with enhanced rate of deep oxidation with concomitant decrease in chlorophyll pigments and chlorophyll a/b ratio. Similar results of increased carotenoid content was reported by Ding *et al.* (2002) in tomato. The lower ethylene emission $hour^{-1}$ with salicylic acid might be due to its possible role in preventing the accumulation of ACC synthase transcripts induced by wounding and inhibited ethylene synthesis by blocking ACC oxidase (Szalai *et al*., 2000). Salicylic acid has also been shown to suppress lipoxy- genase activity in discs of kiwi fruit, with a consequent reduction in the production of free radicals and ethylene biosynthesis (Xu *et al*., 2000). Similar results were reported by Singh and Usha (2003) in wheat.

Salicylic acid spray @ 200 ppm increased the peroxidase and catalase enzymes activity and membrane integrity. The maximum increase in peroxidase activity (27.06 min^{-1} g^{-1}), catalase activity (22.82 µg of H_2O_2 min^{-1} g^{-1}) and membrane integrity (20.43%) was recorded 24 hours after spray. Salicylic acid exerts influence on the activity of peroxidase, participating in the regulation of hydrogen peroxide pool and in the generation of superoxide anion radical on the conditions of presence of surplus of reductants. Under other stress conditions, the level of oxygen radicals is increased, leading to denaturation and inactivation of cytosolic enzymes. Increase in peroxidase and lower electrolyte leakage indicates the involvement of peroxidase in cell membrane integrity. Salicylic acid induced heat tolerance may be because of high oxygen and hydrogen peroxide scavenging potential due to higher peroxidase, catalase and super oxide dismutase activity under heat stress (He, 2004). Similar results were reported by Hayat *et al.* (2008) in tomato. With the application of salicylic acid, the production of catalase gradually increases and it scavenges the hydrogen peroxide production thereby protecting the plant from heat stress. Ding *et al.* (2002) reported that some stress-protective proteins such as catalase, alternative oxidase and heat shock protein (Clarke *et al.,* 2004) could be induced with 0.05 mM exogenous salicylic acid spray which helps in increasing cell membrane integrity. These proteins decrease stress injuries by eliminating reactive oxygen species and preserving the membrane integrity. It was also recorded that salicylic acid application enhances accumulation of polyamines like putrescine, spermine and spermidine in plants which results in higher cell membrane stability (Nemeth *et al.,* 2002). Similar increase in catalase activity with salicylic acid spray was earlier reported by Amal *et al.* (2007) in mung bean. Increase in membrane activity with salicylic acid application was also reported by Mehdi *et al.* (2015) in rose.

Effect of pre harvest sprays on yield parameters

Maximum values in terms yield parameters such as ten flower weight (44.57 g), number of flowers plant^{-1} (41.61), flower yield plant^{-1} (0.19 kg) and flower yield ha^{-1} (158.39 q) was obtained when plants were sprayed with salicylic acid @ 200 ppm (Table 3). The increased flower weight in salicylic acid treatment might be due to the increase in internal gibberillic acid, auxins and ABA levels resulting in stomatal closure eventually reducing the moisture loss from leaves and petals that helped the flowers to retain moisture and weighed more than that of other treatments. Similar results were reported by Dorajeerao and Mokashi (2011) who recorded significant increase in the hundred flower weight of garland chrysanthemum and flower yield plant^{-1} with salicylic acid spray. The increase in the number of flowers plant^{-1} may be due to increase in the production of endogenous bioactive gibberillic acid and changing the hormonal status of the plant. The flowering promoting effect after salicylic acid application can also be indirect as it alters the synthesis and/or signaling pathways of other plant hormones including jasmonic acid, ethylene and auxin which in turn enhance flower promoting factors. Moreover, salicylic acid pre-treatment alleviated the loss of net photosynthetic rate under heat stress, apparently in part through maintaining a higher Rubisco activation state and greater PSII efficiency. Salicylic acid also accelerated the increase of net photosynthetic rate mainly through the more rapid recovery of PSII function after heat stress and may be related to higher levels of heat shock protein 21 (Wang *et al*., 2010). The above mentioned findings were in conformity with Ram *et al.* (2012) in gladiolus. The increase in flower yield ha^{-1} might be attributed to the role of salicylic acid in boosting plant photosynthesis which is directly reflected on plant vegetative, flowering and biomass characteristics by decreasing the chlorophyll damage, increasing the rate of photosynthesis by faster elimination of reactive oxygen species produced during heat stress through increased activity of the scavenging enzymes like peroxidase, catalase and super oxide dismutase. Results in agreement with this study were earlier reported by Pacheco *et al.* (2013) in marigold.

Table 1. Effect of chemicals and plant growth regulators on vegetative parameters of Bidhan Marigold-2

Treatments	Plant height (cm)	Primary branches	Secon-dary branches	ntern-odal length (cm)	IPlant spread (cm) (E-W)	Plant spread (cm) (N-S)	Leaf area (dm^2)	Stem diame-ter at the base (cm)	Specific leaf weight (mg cm^{-2})	Relative water content (%)	Total fresh biomass plant $^{-1}$ (g)	Total dry matter plant $^{-1}$ (g)
Gibberillic acid 150 ppm	83.01	9.13	33.25	4.09	47.33	45.83	47.59	0.67	8.29	92.49 (74.13)	766.39	104.07
Salicylic acid 200 ppm	108.21	13.88	62.63	4.90	59.40	58.18	131.49	1.58	16.11	97.33 (80.87)	1986.04	375.43
Calcium Nitrate 2%	85.63	10.13	40.50	4.22	50.50	48.45	69.38	0.87	9.36	98.31 (82.63)	915.79	160.29
Potassium Nitrate 2%	100.03	12.13	58.13	4.35	54.50	53.55	116.16	1.38	13.05	96.93 (79.96)	1411.47	271.16
28 Homobras-sinolide 1 ppm	90.20	11.25	51.38	4.33	53.94	51.63	78.32	1.17	10.61	95.33 (77.57)	1024.71	185.27
Control	71.31	7.63	30.13	3.95	43.89	42.50	34.68	0.56	6.22	90.79	668.91	75.14
										(72.38)		
S. Em±	0.92	0.18	0.49	0.04	0.72	0.51	1.07	0.04	0.17	0.59	18.18	4.54
CD at 5%	2.77	0.55	1.47	0.11	2.15	1.52	3.21	0.12	0.52	1.79	54.81	13.69

* Figures in parenthesis are arcsine transformed values

Table 2. Effect of chemicals and plant growth regulators on flower characters of Bidhan Marigold-2

Treatments	Days taken to first flower bud appearance	Days taken to 50% flowering	Duration of flowering (days)	Flower diameter (cm)	Length of flower receptacle (cm)	Moisture content in petals (%)	Shelf life of flowers at room temperature (days)	Physiological loss of weight (%)				
								1 Day after Harvest	2 Day after Harvest	3 Day after Harvest	4 Day after Harvest	5 Day after Harvest
Gibberillic acid 150 ppm	37.63	48.95	69.83	3.86	1.90	81.21 (64.35)	3.59	9.90 (18.35)	11.51 (19.84)	15.31 (23.04)	27.27 (31.50)	44.28 (41.73)
Salicylic acid 200 ppm	43.38	58.40	85.38	4.35	1.98	84.36 (66.74)	4.83	4.78 (12.63)	7.21 (15.58)	10.93 (19.31)	19.32 (26.09)	33.85 (35.59)
Calcium Nitrate 2%	45.93	62.43	74.96	3.98	1.91	87.56 (69.39)	4.64	4.15 (11.75)	6.61 (14.90)	10.16 (18.59)	17.22 (24.53)	30.96 (33.82)
Potassium Nitrate 2%	42.50	55.40	82.15	4.18	1.96	83.66 (66.20)	4.28	5.10 (13.06)	8.18 (16.63)	11.65 (19.96)	20.94 (27.24)	37.26 (37.64)
28 Homobrassinolide 1 ppm	41.25	52.35	80.60	4.07	1.94	82.17 (65.06)	3.98	7.13 (15.48)	9.94 (18.38)	13.57 (21.63)	22.75 (28.50)	39.99 (39.24)
Control	34.80	44.48	62.58	3.71	1.78	75.81 (60.59)	2.82	10.40 (18.82)	13.65 (21.69)	16.76 (24.18)	29.54 (32.94)	51.06 (45.63)
S. Em±	0.31	0.47	0.53	0.03	0.003	0.27	0.011	0.17	0.13	0.16	0.17	0.21
CD at 5%	0.95	1.43	1.59	0.08	0.009	0.83	0.035	0.51	0.39	0.49	0.52	0.64

* Figures in parenthesis are arcsine transformed values

Table 3. Effect of chemicals and plant growth regulators on quality and yield parameters of Bidhan Marigold-2

Treatments	Carotenoid content (g kg^{-1} petal)	Ethylene production (ppm $hour^{-1}$)	Increase in			Ten flower weight (g)	Number of flowers $plant^{-1}$	Flower yield $plant^{-1}$ (Kg)	Flower yield ha^{-1} (q)	B:C Ratio
			Peroxidase activity (µM min^{-1} mg^{-1})	Catalase activity (µg of H_2O_2 min^{-1} g^{-1})	Membrane integrity(%)					
Gibberillic acid 150 ppm	1.17	1.34	10.90	7.94	6.45	38.13	36.42	0.14	120.11	1.14
Salicylic acid 200 ppm	1.56	1.07	27.06	22.82	20.43	44.57	41.61	0.19	158.39	3.13
Calcium Nitrate 2%	1.21	1.21	19.84	15.33	12.18	40.10	37.77	0.16	131.03	1.84
Potassium Nitrate 2%	1.39	1.24	24.20	19.62	16.53	42.49	39.46	0.17	141.52	1.66
28 Homobrassinolide 1 ppm 2.17		1.41	1.25	23.29	18.92	16.17	41.28	38.94	0.17	138.35
Control	0.94	1.51	0.29	0.06	0.82	32.73	34.50	0.12	99.13	1.18
S. Em±	0.003	0.006	0.87	0.43	0.54	0.06	0.17	0.001	0.42	-
CD at 5%	0.010	0.019	2.62	1.30	1.64	0.17	0.50	0.002	0.02	-

* Figures in parenthesis are arcsine transformed values

Benefit-cost ratio (BCR)

The highest benefit cost ratio of 3.13 was obtained with pre harvest spray of salicylic acid @ 200 ppm. The benefit-cost ratio was found to be the highest with the application of salicylic acid which is an economically feasible chemical in all ways for inducing heat tolerance and for increasing the flower yield. Brassinosteroids was found to be more beneficial than calcium nitrate and potassium nitrate due to its low cost compared to the other two chemicals.

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PATTERN OF FRESH FRUIT BUNCH (FFB) PRODUCTION AND YIELD DISTRIBUTION OF OIL PALM IN ANDHRA PRADESH

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ABSTRACT

The field study was conducted to evaluate new tenera hybrids at Horticultural Research Station, Vijayarai. As oil palm is a continuous fruit yielding crop in a harvest year, variations in month wise FFB production was studied in tenera hybrid crosses. The performance of hybrids under irrigated conditions planted during 2007 was studied for four years (9 to 12 years after planting) for bunch number, bunch weight and FFB production per ha at monthly intervals. During the four years of study, palms showed significant differences in bunch number, average bunch weight and FFB production in different months of a harvest year. Average bunch weight increased with increase in age of the palms during the study period from 6th to 9th harvest years (11.54 to 14.98 kg) with inverse relation between number of bunches produced per palm and average bunch weight. May, August and September were the months which recorded 40-45 % of total yield of a harvest year while November, December, January and February were the lean production months which recorded lower number of bunches palm^{-1} month^{-1}(0.5) and lower bunch weights month^{-1} (4 to 5 kg) contributing to 10 % annual yield. Cumulative yield of 4 years data shows that there was 18 % and 15% FFB production recorded in May and August months, respectively. Four years mean FFB production was 3.5 t ha^{-1} in August followed by 3 t ha^{-1} in May month. In lean production months (November, December, January and February) per month FFB production was only 0.5 t ha^{-1}. In Andhra Pradesh, peak oil palm FFB production season is 6 months (April to September) and the remaining 6 months (October to March) is lean period.

INTRODUCTION

Oil palm is the highest edible oil yielding perennial crop. It is a monoecious palm which produces male and female inflorescences separately on the same palm. It flowers throughout the year so and Fresh Fruit Bunches (FFB) are produced round the year. Male and female inflorescences are produced in series of cycles with varying durations which lead to yield cycles. In tropical humid climate with regular rainfall (*eg*. Malaysia and Indonesia) inflorescence and fruit production spreads evenly throughout the year. In India, where majority of oil palm is grown under irrigated conditions with seasonal variations in quantum and distribution of rainfall, variations expected in production of bunches and average bunch weight, as these two factors are assumed to

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contribute to combine productivity. Peak oil yield of 12 t ha^{-1} $year^{-1}$ has been achieved in small plantations, yet average oil productivity worldwide has stagnated around 3 t oil ha^{-1} yr^{-1} (Lotte Woittiez *et al*., 2017). It is suggested to study the hybrid/clone performance in local conditions before taking decision on order for planting materials (Rethinam and Murugesan 2018).In Andhra Pradesh, oil yields of 4-5 t ha^{-1} yr^{-1} has been achieved in commercial plantations (IIOPR-2018). Although Fresh Fruit Bunches (FFB) are produced round the year, production peaks are observed during certain period of the year (Corley and Tinker 2003; Henson 2006). Variation in bunch production among different months in a harvest year under irrigated conditions could be due to genetic factor or abiotic factors like high temperature, high rainfall, water stress and improper fertilizer management etc. In oil palm, bunch yield in palms varies with age of palms. Young age palms record less (yield accelerating period 4 years after planting to 8 years after planting) month wise yield variations but in aged palms(20 years after planting) month wise yield variations were more in this regard, monthly bunch production variations was studied at yield stabilizing period (8 years after planting to 12 years after planting), so that it gives clear load of FFB to processing units and also it reflects monthly income per unit area to farmer.

MATERIALS AND METHODS

Ten new oil palm (D X P) cross combinations planted in 2007 were evaluated for 4 years 9th year after planting (2015-16) to 12th year after planting(2018-19) for their production performance. The experiment was laid out in a Randomized Block Design (RBD) and replicated thrice at Horticultural Research Station, Vijayarai, (16.81^0N, 81.03^0E) West Godavari District of Andhra Pradesh. Normal average annual rainfall of the region is in the range of 800-900 mm. Ten crosses (NRCOP-1 to NRCOP-10) developed at ICAR-Indian Institute of Oil palm Research (ICAR-IIOPR), Pedavegi, West Godavari District of Andhra Pradesh (Table1) were used for the experiment. Spacing of the palms was 9m x9m x9m (Triangular) accommodating 123 palms per hectare.The plantation was under irrigated condition with 1200:600:1200 g of N: P: K application per palm in four splits at quarterly intervals and 500 g of magnesium sulphate and 100 g of borax application per palm in two splits in a year. All the recommended package of practices was followed during the study period. Observations were recorded by following standard methods. All the mature fruit bunches were harvested at 11-13 days interval, starting from 4th year after planting to 13 years (10 harvest years). For this study, data was taken for each palm, added two harvests of a month and reported as data of that moth (from 6th harvest year to 9th harvest year coinciding with 6 to 12 Years Age of the Palms (YAP)). Every bunch was weighed along with loose fruits using a balance mounted on a tripod. The bunch weight recorded from sampling palms was divided by number of palms to obtain bunch weight per palm, which was then multiplied by number of palms per hectare to obtain total bunch weight (FFB yield) per hectare per year. FFB yield recorded for 10 years (four years after planting to 13 years after planting)were totaled to get cumulative yield. All the data were summarized according to treatments and subjected to statistical analysis, least significant differences (LSD) test, at significance level of 5%.

RESULTS AND DISCUSSION

Variations in bunch production at monthly intervals

Number of bunches produced per palm per month varied significantly at yield stabilizing period of palms(9-12 years after planting) that is at 6th,7th,8th and 9th harvest years. During 6th and 8th harvest years August was the month where significantly highest number of bunches were produced by the palms (2.17 and 2.90, respectively).In the 9th harvest year, number of bunches produced by the palms were significantly highest in the month of May (2.25) while during 7th harvest year bunch production was on par in three months i.e., March,August andSeptember (1.32, 1.41 and 1.27, respectively) (Table 1). During 6th and 7th harvest years, number of bunches produced per palm in each month showed less variation ,while in 8th and 9th harvest years much variations were observed with clear lean period from October to March and with a peak production months during April to September (Table 1).The number of ripe bunches available for harvest is determined by the number of inflorescences initiated (which in-turn depends on the rate of leaf production), leaf initiation rate (primarily determined by palm age) (Broekmans,1957), sex ratio, abortion of female inflorescence before anthesis, failure of developing bunches between anthesis and bunch ripeness, (LotteWoittiez *et al*., 2017). Annual yield data recorded for 6 years at IIOPR indicated a production trend of on (high production) and off (low production) years which is comparable to that of alternate bearing in other fruit crops (Naveen Kumar *et al*., 2017).Palms produced no bunches at 32 to 35 months interval. Cumulative bunch production follows the same trend as that of number of bunches produced per palm per month. Cumulative bunch production was significantly highest in the month of August (950.81 bunches produced per hectare) in 4 harvest years of yield stabilizing period. During 6th harvest year bunch production was 1429.82 bunches per hectare which was reduced to 1303.13 bunches ha^{-1} in 7th harvest year with a reduction of 126 bunches per hectare and again during 8th harvest year there was a rise to the tune of 100 bunches per hectare, again in the 9th harvest year palms produced 144 less number of bunches per hectare (Table 2). Mean number of bunches produced per palm was highest in the month of August (1.9 bunches per palm) followed by September and May months (1.5 bunches per palm). June–July months recorded 1.2 and 1 bunches per month while January and February are the months which recorded lowest number of bunches per month (0.4 and 0.3) (Fig: 1), Again from March to September there was rise in bunch production. There was on and off trend for bunch production in palms, in every alternate year. From the above data it is evident that April to September are the peak bunch production months, while October to March were lean months for bunch production. Corley and Tinker and Hanson 2006 reported that although the vegetative growth and development are continuous and constant under favorable conditions there were strong seasonal variations of reproductive growth in oil palm.

Average bunch weight variation in different months of a harvest year

During 6th and 7th harvest years, palms produced highest average bunch weight during March-April-May and August-September months with average bunch weight range of 12.36 kg to

15.17 kg. Lowest bunch weight was recorded in the month of November in all the four harvest years (Table 1). During 8th harvest year, only April and May months produced significantly highest average bunch weight (19.73 and 19.21 kg, respectively) while during 9th harvest year from the month of April to August average bunch weights were recorded significantly highest from April to August which were on par with each other. There was on and off trend for average bunch weights. There was 3.25 kg increase in bunch weight from 6th harvest to 7th harvest year. Again there was fall in 8th harvest year up to 1.3 kg. Again during 9th harvest year the rise was up to 1.49 kg of average bunch weight. Average bunch weight increased with increase in age of the palms. With increase in age of the palms, the sex- ratio decreases thereby number of bunches produced per palm per year are reduced, which in-turn increases average bunch weights (Rethinam, 1998 and Madhavi Latha *et al*., 2016).The bunch maturation time (from anthesis to bunch ripeness) varies from 140 to 180 days, depending on both genetic and environmental factors (Henson, 2005). If bunch production is less in a harvest year (off year), then average bunch weight in that harvest year was more (on year). Hence, there was inverse relation between numbers of bunches produced per palm and average bunch weight of that harvest year.

Fresh Fruit Bunch (FFB) yield variations at monthly intervals

During 6th, 7th and 8th harvest years, August was the month which recorded the highest FFB yield. During 6th harvest year, May, August and September were the months which recorded on par yields of 21.93, 27.30 and 22.63 kg/palm/month (2.86, 2.76 and 2.66 t ha^{-1} respectively) while during 7th harvest year August, September and March months recorded on par yields of 23.29,22.46 and 21.64 kg/palm/month, respectively (2.86,2.76,2.66 t ha^{-1}).During 8th harvest year, August was the month which recorded significantly highest FFB yield 45.21 kg/palm recording 5.36 t ha^{-1} reflecting 25% of yield of that harvest year. During 9th harvest year May was the month which recorded significantly highest yield of 40.49 kg/palm giving 4.98 t ha^{-1} (Table 1&2). From 6th to 8th harvest year there was an increase in yield trend (140 to 177 kg/ palm/year) but during 9th harvest year there was 13 kg/palm/year yield reduction was there. FFB production was 17.2,19.6,21.81 and 20.23 t ha^{-1} during 6th,7th,8th and 9th harvest years with a four years cumulative yield of 78.94 t ha^{-1} (Table 2). Corley (1976) noted that in West Africa, the period of lowest sex ratio (high male inflorescence production) occurs during the rainy season and speculated that this character is an adoption against the reduction in air borne pollen density caused by high atmospheric density. Flowering in the month of June to October under long days might be the reason for low yields in winter months because flower opening to FFB harvest it takes 5-6 months. Lower average bunch weight during winter harvested FFBs might be due to less pollination and fertilization during rainy season as pollen wash off happens.

Cumulative yield of 4 years recorded a production of 950 bunches in August month recording FFB yield of 14.20 t ha^{-1} followed by 12.43 t ha^{-1} in May month (Table:2).Highest mean yield of 3.5 t ha^{-1} was recorded in the month of August followed by May which recorded 3.0 t ha^{-1} (Fig. 1). November, December, January and February were the four lean months which recorded only 0.5-0.6 t ha^{-1} month^{-1} which was

Table 1. Production performance and month-wise yield trends of oil palm at yield stabilizing period

Month of harvest	Number of bunches/palm/month				Average bunch weight (kg)				FFB yield (kg/palm/month)			
	*9th/ ⁂6th	*10th/ ⁂7th	*11th/ ⁂8th	*12th/ ⁂9th	*9th/ ⁂6th	*10th/ ⁂7th	*11th/ ⁂8th	*12th/ ⁂9th	*9th/ ⁂6th	*10th/ ⁂7th	*11th/ ⁂8th	*12th/ ⁂9th
April	0.36	0.95	1.22	1.07	12.38	16.69	19.73	17.21	4.55	15.95	24.17	18.48
May	1.44	0.79	1.33	2.25	15.17	16.58	19.21	17.88	21.93	13.02	25.67	40.49
June	1.13	0.59	1.62	1.25	12.27	15.41	15.89	18.76	13.76	9.14	25.88	23.72
July	0.37	0.61	1.44	1.56	11.47	14.56	15.70	15.99	4.17	8.88	22.69	25.21
August	2.17	1.41	2.90	1.25	12.36	16.45	15.61	15.61	27.30	23.29	45.21	19.70
September	1.79	1.27	1.50	1.25	12.59	17.65	14.26	13.93	22.63	22.46	21.28	17.55
October	1.06	1.03	0.62	0.63	9.45	12.36	8.91	10.85	9.96	12.81	5.60	6.85
November	0.47	0.75	0.31	0.30	6.73	10.24	6.77	10.82	3.15	7.80	2.20	3.18
December	0.62	0.74	0.25	0.30	8.26	12.34	9.48	11.07	5.15	8.59	2.40	3.35
January	0.70	0.60	0.15	0.13	12.41	14.78	10.83	16.06	8.53	8.96	1.68	2.24
February	0.64	0.54	0.05	0.09	11.55	14.07	12.05	16.27	7.38	7.50	0.64	1.56
March	0.83	1.32	0.00	0.13	13.84	16.38	0.00	15.28	11.55	21.64	0.00	2.16
Annual(Apr-Mar)	11.61	10.62	11.42	10.24	11.54	14.79	13.49	14.98	140.06	160.03	177.43	164.49
CD(0.05)	0.36	0.28	0.41	0.31	2.81	1.83	3.42	3.54	5.71	4.76	7.26	6.54

***Age of palm / ⁂ year of harvest**

Table 2 . Month-wise cumulative production performance of oil palm during yield stabilizing period (6^{th} to 9^{th} harvest years)

Month of harvest	Number of bunches/month/ha				Cumulative	FFB yield (t/month/ha)				Cumulative
	$*9^{th}$/ ⁂ 6^{th}	$*10^{th}$/ ⁂ 7^{th}	$*11^{th}$/ ⁂ 8^{th}	$*12^{th}$/ ⁂ 9^{th}		$*9^{th}$/ ⁂ 6^{th}	$*10^{th}$/ ⁂ 7^{th}	$*11^{th}$/ ⁂ 8^{th}	$*12^{th}$/ ⁂ 9^{th}	
April	45.14	117.53	149.92	132.02	444.62	0.56	1.96	2.97	2.27	7.76
May	178.08	97.72	163.59	277.43	716.82	2.69	1.6	3.15	4.98	12.43
June	139.67	73.12	199.81	154.84	567.44	1.69	1.12	3.18	2.92	8.91
July	46.06	75.17	177.39	192.29	490.91	0.51	1.09	2.79	3.1	7.49
August	266.92	173.57	356.43	153.89	950.81	3.36	2.86	5.56	2.42	14.20
September	220.31	156.48	184.36	153.89	715.04	2.78	2.76	2.61	2.16	10.32
October	131.20	126.42	77.35	78.17	413.14	1.22	1.57	0.68	0.84	4.32
November	58.22	92.93	38.13	36.49	225.77	0.38	0.95	0.27	0.39	2.00
December	76.81	86.10	31.43	37.31	231.65	0.63	1.05	0.29	0.413	2.39
January	86.65	74.48	19.12	16.54	196.79	1.05	1.1	0.20	0.27	2.63
February	78.58	66.28	6.16	11.34	162.37	0.90	0.92	0.07	0.19	2.10
March	102.36	163.32	0.00	15.72	281.40	1.42	2.66	0.00	0.26	4.34
Annual(Apr-Mar)	**1429.82**	**1303.12**	**1403.70**	**1259.93**	**5396.57**	**17.2**	**19.6**	**21.81**	**20.23**	**78.94**
CD(0.05)	44.73	35.02	51.07	38.56	169.38	0.70	0.58	0.89	0.805	2.98

***Age of palm / ⁂ year of harvest**

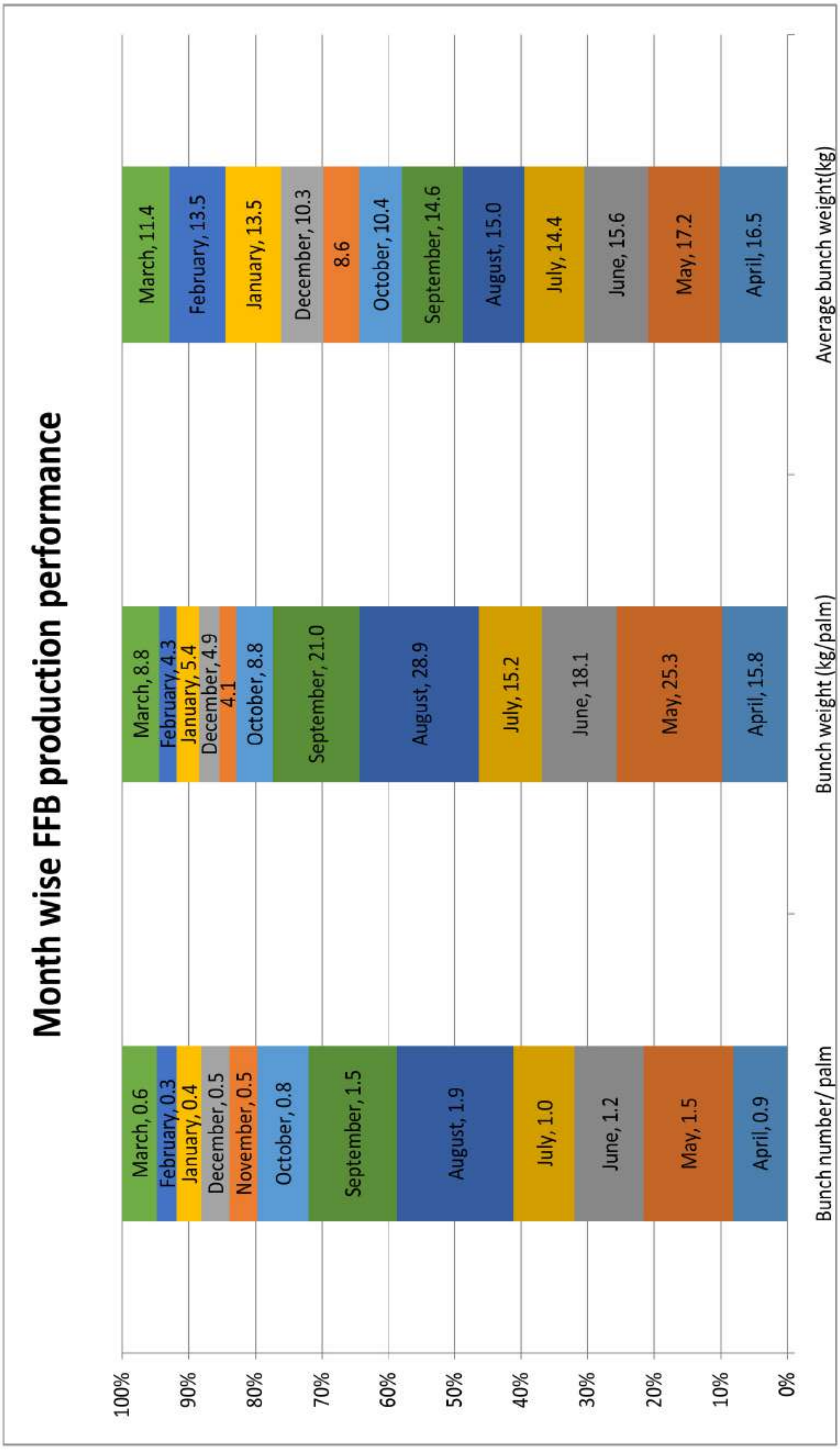

Fig. 1 Mean production performance of oil palm for four years at yield stabilizing period (April to March)

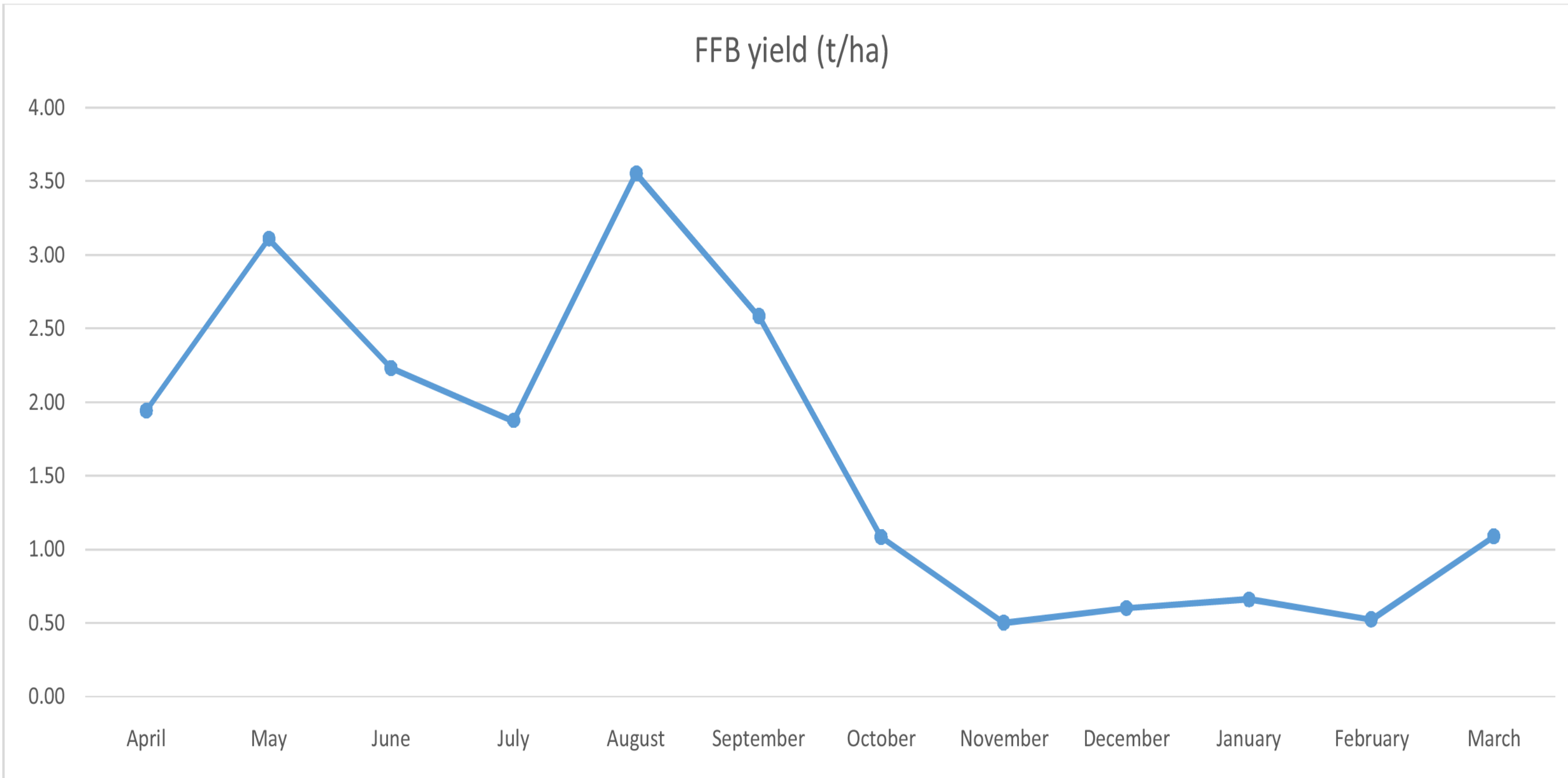

Fig. 2. Mean FFB production (four years average) during yield stabilizing period (April to March)

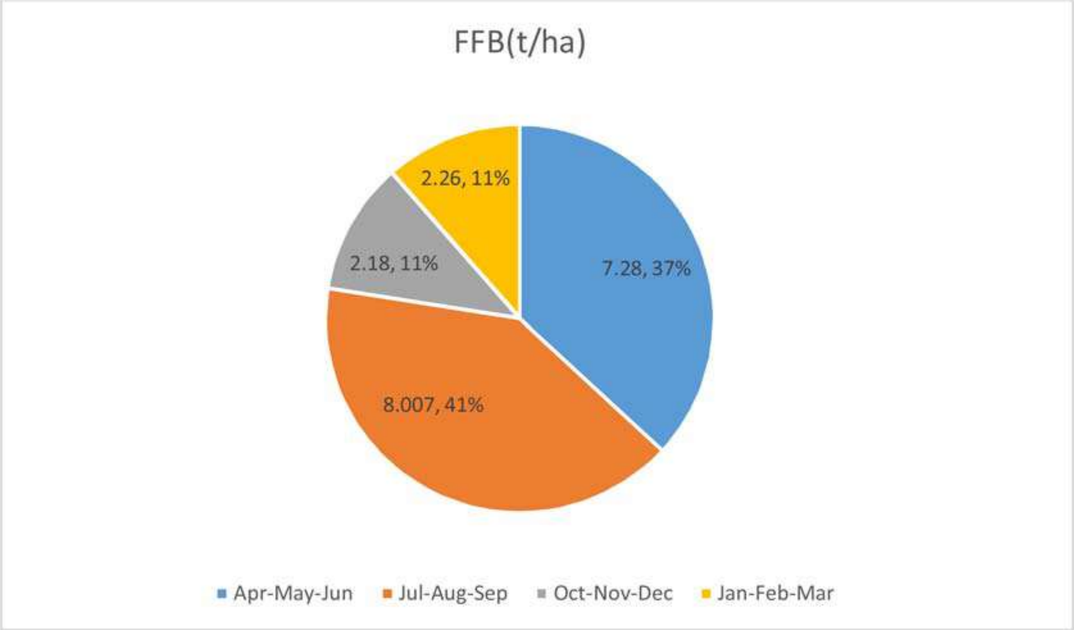

Fig. 3. Quarter wise percent FFB production yield stabilizing period in oil palm

only 10% of yield per year. March and October months recorded FFB yield of 1 t ha^{-1}. From the Fig.1 mean yield data reflects that May, August and September are the peak harvest months recording 45% of yield per year. Under irrigated conditions of Andhra Pradesh where temperature and sunshine hours are not limiting for oil palm plantations, reasons are to be identified for lean production of FFB in four months (November to February). In Andhra Pradesh June to September are the four monsoon months, flowering in rainy season leads to washing out of pollen and low fertilization leads to poor fruit set and less yields in November, December, January and February months. In oil palm from flower opening and pollination to bunch harvest it takes 5 to 6 months. Poor activity of pollinating weevil during rainy season (Crooly 1976a). Henson (2006) also reported that annual production is continuous but generally shows marked seasonal peaks which can be neither be explained by carbon assimilation nor phenology alone.

CONCLUSION

In Andhra Pradesh state, oil palm new tenera crosses recorded peak FFB yields during May, August and September months (Four years of trial mean,2015-16 to 2018-19) contributing to 46% of annual yield in the above three months period. Number of bunches produced per palm per month was highest during August (1.9) and lowest during February (0.3). Average bunch weight variations were there in a production year, highest average bunch weight recorded during May (17.2kg) and lowest during October (8.6 kg). FFB yields recorded were 3.10, 3.55 and 2.58 t ha^{-1} during May, August and September months respectively. April to September is the oil palm peak production season contributing to 78 % annual yield. In yield stabilizing period (8-12 years palms), highest FFB yield recorded at 11 years after planting (8th harvest year).Palms recorded cumulative yield of 78.94 t ha^{-1} in yield stabilizing period.

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PERFORMANCE OF DIFFERENT OPEN-POLLINATED BRINJAL VARIETIES GROWN BY ORGANIC AMENDMENTS UNDER EASTERN INDIAN PLATEAU OF JHARKHAND

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ABSTRACT

The research was conducted to study the efficiency of organic amendments in seven brinjal cultivars. As organic sources, the performance of liquid manures *viz.,* Sasyagavya, and *enriched* Sanjeevani were compared with untreated (control) for growing seven open-pollinated varieties namely HABR-21, Swarna Abhilamb, Swarna Shree, Swarna Shobha, Swarna Pratibha, Swarna Mani, and Swarna Shyamli. Different growth, yield, and quality attributing characters were studied and Swarna Shyamli wasfound to give the highest yield (63.50 t. ha^{-1}) under *Enriched Sanjeevani* treatment. Besides, Swarna Shree performed well in the expression for growth and yield attributes. Reducing sugar (6.76%) and ascorbic acid content (32.21 mg $100g^{-1}$) were found to be the highest in Swarna Mani. In general, *Enriched Sanjeevani* was observed to be better performing treatment compared to *Sasyagavya* and *Untreated* (*control)*. Therefore, it might be concluded that Swarna Shyamli and Swarna Shree are suitable brinjal varieties for organic cultivation using Enriched *Sanjeevani* (10%).

Keywords: Brinjal, *Sasyagavya*, *Sanjeevani*, Yield, Quality

INTRODUCTION

Brinjal (*Solanum melongena* L.) is an important solanaceous crop of sub-tropics and tropics.Based upon its high production potential and availability of the produce to consumers, it is also termed as poor man's vegetable. Brinjal is commercially grown in India, Bangladesh, Pakistan, China, and the Philippines. In India, major brinjal-producing states are Odisha, Bihar, Karnataka, West Bengal, Uttar Pradesh, and Maharashtra. Nutritionally, it is an important vegetable containing vitamins (A, B, C, and K) and minerals (iron, phosphorous, and calcium). It also has *ayurvedic* properties, hence, is being used as a medicine for curing diabetes and several liver problems. Apart from this, it is a good appetizer, aphrodisiac, and laxative also. India is the second-largest producer of the Brinjal next to China contributing about 23.3% of the total global production.

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Brinjal crop is being sprayed 20-25 times with pesticides whose residues in fruits are leading to health hazards (Hill *et al.*, 2018). On the contrary,the increasing cost of chemical fertilizers became unyielding for the small and marginal farmers. Hence, a cost-saving and sustainable approachto crop production should be adopted to minimize the growing risk of present-day's chemical farming practices. One such sustainable approach could be the use of organic inputs.Organic sources of nutrients have been observed to be useful and economically viable on several crops. They enhance growth, yield, as well as the overall productivity of the crops apart from ensuring safe and superior quality,produce (Reganold and Wachter, 2016; Seufert and Ramankutty, 2017). It also improves soil and plant health.Earlier studies have suggested the utility of organic nutrient sources in brinjal production (Singh *et al.*, 2000). Organic farming largely consists of using organic manures and composts as their main source of nutrition. However, due to their bulkiness and limited availability, resource-poor farmers find it difficult to procure them at times of need. Under such conditions, liquid organic manures like *Sasyagavya, Panchagavya, Jeevamrutha, etc.* could be readily prepared from locally available resources, and their application at regular intervals could increasethe productivity of different crops (Devakumar *et al.*, 2014; Sornalath *et al.*, 2018; Mahto and Dutta, 2018). Keeping this in view, the study was conducted usingseven commonly grown open-pollinated cultivars of brinjal to evaluate their performance with the application of different organic liquid manures.

MATERIAL AND METHODS

Experimental site and season

The experiment was conducted at the Organic Experimental Farm of Agriculture, Rural and Tribal Development Faculty Centre, Morabadi, Ranchi for two successive *rabi* seasons of 2018-19 (Year-1) and 2019-20 (Year-2). This experimental site is situated on the southern part of the Chhota Nagpur plateau which forms the eastern edge of the Deccan plateau under the typical humid subtropical climatic region at 23.23°N latitude and 85.23°E longitude. The average soil reaction of the experimental site was 6.32. The soil in the experimental plot was porous sandy loam type with available organic carbon, N, P_2O_5, and K_2O estimated as0.67 (%), 263.42 (kg ha^{-1}), 19.38×10^{-3}(%) and 52.89×10^{-3}(%), respectively. The total bacterial and fungus population of the experimental site were 116×10^{-5} $cfu.ml^{-1}$ and 89×10^{-5} $cfu.ml^{-1}$, respectively.

Experimental materials

Seven open-pollinated varieties of the crop *viz.*V_1: HABR-21, V_2: Swarna Abhilamb, V_3: Swarna Shree, V_4: Swarna Shobha, V_5: Swarna Pratibha, V_6: Swarna Mani, and V_7: Swarna Shyamli were evaluated through organic farming by using different organic sources of plant production and protection inputs. Performance of those varieties with their four times replication was evaluated under three treatmentsituates*viz.*, T_1:*Sasyagavya* (10%); T_2: *Enriched Sanjeevani* (10%); and T_3: *Untreated Control*. From our earlier studies, it was found that 10% concentration of both of the liquid manures is highly effective in brinjal (Rajak *et al.*, 2019).There were four replications in each treatment. A basal dose of one kg vermicompost per square metre area was applied in all experimental plots. Different organic liquid manures were applied (as per the specified treatment) five times at 15 days intervals starting after 15 days of transplanting. As a prophylactic measure of plant protection, neem leaves extract (10%) was applied thrice at fortnightly intervals started at 15 days after sowing. While under the untreated control growing condition (T_3), no input was applied except for a basal dose.

Preparation of Sasyagavya

Sasyagavya, a liquid organic manure was prepared by mixing fresh cow dung: cow urine: kitchen waste: water @ 1: 1: 1: 2 proportions by w/w basis(cow dung and cow urine should be of indigenous cow's origin) and kept the mixture for nine daysfor fermentation. The mixture was stirred by a wooden ladle twice daily during the morning and evening hours in clockwise and anticlockwise directions for enhancing the process of fermentation.

Preparation of *Enriched Sanjeevani*

Sanjeevani is a quick fermented liquid manure that was prepared by mixing fresh cow dung: cow urine and water @ 1:1:2 proportionby w/w basis. It was further mixed with jaggery (molasses) and pulse flour @ 50g each per kg of mixture for enriching the plant nutrients and enhancing the fermentation by 3-5 days (depending on the prevalent temperatures). The mixture was stirred as described above for proper aeration and fermentation.

Calculation of the dose of liquid manures

In both of the above cases of organic liquid manures, 50% concentration was obtained (considering one part of cow urine against two parts of water) and required concentration was prepared by diluting with water concerning the formula, $V_1S_1 = V_2S_2$ (wherein, V_1& V_2 represent the initial & final volume, and S_1& S_2 represent the initial & final strength, respectively).

Experimental design and planting

Randomized Complete Block Design (RCBD) was adopted in conducting field experiment by incorporating seven varieties with four replications under threetreatment conditions (T_1, T_2&T_3) in 84 experimental plots each of 3.0 m × 2.0 m sizes. Five weeks old seedlings of described varieties were planted in each of the experimental plots with 60 cm X 50 cm spacing.

Observations recorded

Growth and yield attributes such as plant height (at peak fruiting stage), number of fruits plant^{-1}, fruit weight (g), and yield (t ha^{-1}) were taken from time to time for the study. Proximate quality attributeslike Total Soluble Solids (°Brix), titrable acidity (%), ascorbic acid (mg 100g^{-1}), andReducing Sugar (%)were also determined.

Methodologies adopted for proximate quality traits analysis

Standard methods were adopted for estimation of the TSS [by ERMA Hand Refractometer], Titrable Acidity (TA), ascorbic acid[as per Highet and West, 1942], andreducing sugar [by Lane and Eynon Method] content of freshly harvested fruits.

Statistical analysis

Data on different growth, yield, and proximate quality were analyzed as per the standard procedure for Analysis of Variance (Gomez and Gomez, 1984). The significance of varieties was tested by 'F' test, and standard error of mean (SEm±) was computed in all cases. The difference in the mean under different varietal situates was tested by using critical difference (CD) at a 5% level of significance. For interpretation of data, pooled mean values of both years were considered.

RESULTS AND DISCUSSION

Growth and yield attributes

Data from Table 1 showed that among varieties, plants belonging to Swarna Shree (V_3) were found to have the highest plant height (91.60cm) when treated with 10% solution of *EnrichedSanjeevani* (T_2). However, plant height in the same variety was 89.05cm in 10% *Sasyagavya* (T_1) and 57.00cm in the untreated control condition(T_3).In general, 10% solution of *Enriched Sanjeevani* (T_2)showed superior plant height in almost all the varietieswhen compared with the other two treatments. Though plant height is attributed genetically, microenvironmental conditions also play a major role in the expression of this genetic trait.Number of fruits per plant also differed significantly amongst the seven varieties studied. A higher number of fruits per plant (7.70) was observed in Swarna Shree (V_3) with the application of 10% *Enriched Sanjeevani* (T_2). However, the same variety produced 7.28 under T_1 and 1.94 under untreated control conditions (Table 1). All the varieties performed well under the influence of 10% *Enriched Sanjeevani* (T_2) condition probably due to more efficacy of supplying plant nutrients from this liquid organic manure.

Fruit weight (379 g) was the highest in Swarna Shyamli (V_7) under the influence of 10% solution of *Enriched Sanjeevani* (T_2) followed by 367 g in 10% *Sasyagavya*(T_1) but mere 130 g in Control conditions (Table 2). Consequently, Swarna Shyamli (V_7) emerged as the highest yielding (64.00t ha^{-1}) variety under the influence of 10% solution of *Enriched Sanjeevani* (T_2). This variety also gave a yield of 62.10 t ha^{-1} under T_1 (10% *Sasyagavya*) condition. All other varieties also performed better underT_2 treatment condition (Table 2). Better growth and consequently more yield realized in 10% *Enriched Sanjeevani* (T_2) treatment condition than its respective other two treatment counterparts. This might be due to the enhanced activity of soil microbes in *Enriched Sanjeevani applied* soils that helped in assimilating more nutrients to the plants and thus resulting in their higher growth and yield.The presentfindings are in close accordance with the findings of Singh (2006); Bindhumati (2008);Hari *et al.* (2007) and Chaturvedi *et al.*(2016).

Proximate quality contributing attributes

Most of the observed quality attributing traits were found to be statistically significant **(Pd"0.05)**under the three different treatment conditions. TSS content was found to be highest (4.90°Brix) inSwarna Shobha (V_4) in 10% *Enriched Sanjeevani*(T_2) treatment condition (Table 3). The same variety had 4.20º Brix and 3.35 º Brix in 10% *Sasyagavya*(T_1) and Untreated Control (T_3) treatments, respectively (Table 3). Higher TSS content in T_2 treatment condition observed in almost all varietal conditions might be due to higher microbial activity in the *Enriched Sanjeevani* applied soil leading to increased efficiency in the uptake of macro-and micro-nutrients. Similarly, Titrable acidityalso showed significant differences **(Pd"0.05)** among the seven varieties under different treatment

Table 1. *Per se* performance of plant height (cm) and number of fruits plant^{-1} of brinjal varieties as influenced by different organic liquid manures

Variety	Plant height (cm)									Fruits plant^{-1}								
	Year-1			Year-2			Pooled data			Year-1			Year-2			Pooled data		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
V_1	72.10	89.10	35.20	83.40	91.20	31.00	77.75	90.15	33.10	4.50	5.80	2.00	5.21	5.80	1.14	4.85	5.80	1.57
V_2	72.90	78.50	65.60	75.60	82.83	71.67	74.25	80.67	68.64	4.80	5.30	2.10	5.00	5.40	1.98	4.90	5.35	2.04
V_3	89.10	90.60	56.40	89.00	92.20	57.60	89.05	91.60	57.00	7.00	7.60	2.50	7.57	7.80	2.76	7.28	7.70	2.63
V_4	81.50	87.20	54.50	82.50	87.00	56.17	82.00	87.10	55.34	5.50	5.70	2.26	6.65	5.74	2.60	6.08	5.72	2.43
V_5	68.50	73.80	55.20	69.50	74.87	75.60	69.00	74.34	65.40	6.00	6.50	2.10	6.00	6.60	1.78	6.00	6.55	1.94
V_6	78.20	78.60	46.00	78.00	79.40	44.67	78.10	79.00	45.34	4.20	4.80	2.40	4.50	5.10	2.72	4.35	4.95	2.56
V_7	69.40	71.40	48.00	70.20	71.15	47.33	69.80	71.28	47.67	6.10	6.82	2.70	6.41	6.90	2.58	6.26	6.86	2.64
SEm±	1.26	7.80	4.20	1.78	8.78	5.30	1.52	8.29	4.75	0.26	0.16	0.15	0.30	0.20	0.17	0.28	0.18	0.16
CD @5%	3.21	10.50	12.50	8.00	8.60	8.20	5.61	9.55	10.35	0.55	0.31	0.28	0.65	0.49	0.40	0.60	0.40	0.34

T_1:*Sasyagavya*(10%); T_2: *Enriched Sanjeevani*(10%); and T_3: Untreated Control; For Varieties:V_1: HABR-21; V_2: Swarna Abhilamb; V_3: Swarna Shree; V_4: Swarna Shobha; V_5: Swarna Pratibha, V_6: Swarna Maniand V_7: Swarna Shyamli

Table 2. ***Per se*** **performance of fruit weight (g) and yield (t ha^{-1}) of brinjal varieties as influenced by different organic liquid manures**

Variety	Fruit weight (g)									Yield (t ha^{-1})								
	Year-1			Year-2			Pooled data			Year-1			Year-2			Pooled data		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
V_1	246	258	120	251	252	96	249	255	108	51.20	55.20	21.20	52.80	56.20	22.18	52.00	55.70	21.69
V_2	261	282	80	176	183	72	219	233	76	61.80	63.00	27.20	61.20	63.50	29.15	61.50	63.25	28.17
V_3	164	184	92	168	180	103	166	182	98	60.10	62.40	22.10	61.40	63.20	21.00	60.75	62.80	21.55
V_4	286	304	110	268	298	120	277	301	115	55.70	58.10	25.50	56.20	58.60	20.10	55.95	58.35	22.80
V_5	310	320	104	321	336	106	316	328	105	42.30	44.60	26.60	43.10	45.00	26.98	42.70	44.80	26.79
V_6	286	298	126	274	295	118	280	297	122	58.00	59.10	28.30	58.50	59.00	28.20	58.25	59.05	28.25
V_7	362	378	134	371	380	126	367	379	130	62.30	64.50	20.10	62.00	63.50	22.20	62.15	64.00	21.15
SEm±	0.01	4.8	8.56	0.01	5.8	9.36	0.01	5.30	8.96	4.30	1.50	1.60	5.38	1.46	1.56	4.84	1.48	1.58
CD@5%	0.018	11.1	18.54	0.02	11.9	20.52	0.02	11.50	19.53	10.40	3.00	3.20	10.68	3.44	3.68	10.54	3.22	3.44

T_1:*Sasyagavya*(10%); T_2: *Enriched Sanjeevani* (10%); and T_3: Untreated Control; For Varieties:V_1: HABR-21; V_2: Swarna Abhilamb; V_3: Swarna Shree; V_4: Swarna Shobha; V_5: Swarna Pratibha, V_6: Swarna Maniand V_7: Swarna Shyamli

Table 3 .*Per se* performance of TSS(ºBrix) and TA (%) of brinjal varieties as influenced by different organic liquid manures

Variety	TSS(ºBrix)									TA(%)								
	Year-1			Year-2			Pooled data			Year-1			Year-2			Pooled data		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
V_1	4.00	4.60	3.56	3.90	4.40	3.57	3.95	4.50	3.57	0.18	0.22	0.12	0.20	0.25	0.13	0.19	0.24	0.12
V_2	4.10	4.50	3.40	4.10	4.40	3.40	4.10	4.45	3.40	0.20	0.22	0.16	0.24	0.29	0.14	0.22	0.26	0.15
V_3	3.90	3.90	3.50	3.90	4.10	3.40	3.90	4.00	3.45	0.12	0.16	0.12	0.12	0.15	0.22	0.12	0.16	0.17
V_4	4.20	5.00	3.20	4.20	4.80	3.50	4.20	4.90	3.35	0.19	0.22	0.16	0.18	0.23	0.22	0.18	0.23	0.19
V_5	3.60	4.10	3.00	4.10	4.30	3.07	3.85	4.20	3.03	0.20	0.26	0.16	0.18	0.25	0.16	0.19	0.26	0.16
V_6	3.90	4.50	3.70	4.10	4.50	3.80	4.00	4.50	3.75	0.26	0.33	0.13	0.28	0.35	0.17	0.27	0.34	0.15
V_7	4.40	4.60	3.65	4.20	4.70	3.82	4.30	4.65	3.73	0.16	0.19	0.13	0.20	0.22	0.19	0.18	0.21	0.16
SEm±	0.21	0.15	0.18	0.23	0.18	0.34	0.22	0.17	0.26	0.01	0.02	0.02	0.04	0.15	0.03	0.03	0.09	0.03
CD@5%	0.38	0.60	0.65	0.22	0.46	0.49	0.30	0.53	0.57	0.03	0.05	0.05	0.09	0.33	0.06	0.06	0.19	0.06

T_1:*Sasyagavya*(10%); T_2: *Enriched Sanjeevani* (10%); and T_3: Untreated Control;For Varieties:V_1: HABR-21; V_2: Swarna Abhilamb; V_3: Swarna Shree; V_4: Swarna Shobha; V_5: Swarna Pratibha, V_6: Swarna Mani; and V_7: Swarna Shyamli

Table 4. ***Per se*** **performance of Ascorbic acid (mg $100g^{-1}$) and reducing sugar (%) content of brinjal varieties as influenced by different organic liquid manures**

Variety	Ascorbic acid (mg $100g^{-1}$)									Reducing sugar (%)								
	Year-1			Year-2			Pooled data			Year-1			Year-2			Pooled data		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
V_1	22.50	24.04	15.38	18.26	23.08	15.38	20.38	23.56	15.38	4.00	4.23	3.40	4.10	4.79	3.93	4.05	4.51	3.66
V_2	28.80	30.10	22.30	28.60	30.77	26.64	28.70	30.44	24.47	4.90	5.80	5.20	4.13	7.79	4.87	4.51	6.80	5.03
V_3	25.69	27.20	17.00	23.08	26.92	18.90	24.38	27.06	17.95	5.00	6.10	5.28	5.51	6.03	5.39	5.25	6.07	5.34
V_4	21.65	23.00	18.15	18.90	22.51	27.28	20.28	22.76	22.72	4.85	5.50	4.40	4.65	6.12	5.13	4.75	5.81	4.76
V_5	21.80	23.08	19.20	22.18	23.08	19.03	21.99	23.08	19.11	4.33	4.25	7.60	4.55	4.77	1.24	4.44	4.51	4.42
V_6	23.08	31.20	15.24	28.50	33.23	15.53	25.79	32.22	15.38	4.23	6.24	5.30	4.40	7.28	4.94	4.32	6.76	5.12
V_7	21.28	23.50	18.30	19.23	24.20	17.60	20.26	23.85	17.95	4.00	4.12	2.80	4.21	4.23	2.20	4.11	4.18	2.50
SEm±	12.66	7.57	5.53	3.14	1.33	5.53	7.90	4.45	5.53	0.38	0.17	0.80	0.30	0.19	0.62	0.34	0.18	0.71
CD@5%	NS	16.49	NS	6.80	2.89	12.05	6.80	9.69	12.05	NS	0.38	1.56	0.14	0.42	NS	0.14	0.40	1.56

T_1: *Sasyagavya*(10%); T_2: *Enriched Sanjeevani* (10%); and T_3: Untreated Control; For Varieties:V_1: HABR-21; V_2: Swarna Abhilamb; V_3: Swarna Shree; V_4: Swarna Shobha; V_5: Swarna Pratibha, V_6: Swarna Mani; and V_7: Swarna Shyamli conditions. Values were the highest (0.034%) in Swarna Mani (V_6) followed by 0.26% in Swarna Pratibha (V_5) and Swarna Shree (V_3) under the *Enriched Sanjeevani (10%)* treatment condition (T_2).

Ascorbic acid and reducing sugar content in seven varieties showed significant differences among each other under the influence of three different treatments when their pooled values were considered (Table 4). Higher ascorbic acid content (32.22 mg $100g^{-1}$) was recorded in Swarna Mani(V_6) under *Enriched Sanjeevani* treatment condition (T_2). Most of the varieties performed better in ascorbic acid content under the treatment condition of 10% *Enriched Sanjeevani* (T_2). Swarna Avilamb (V_2) recorded the highest reducing sugar content (7.79%) followed by (7.28%) in Swarna Mani (V_6) with 10% *Enriched Sanjeevani* (T_2) applied condition (Table 4).The findings onascorbic acid and reducing sugar as recorded in the studyare in line with the findings of Kandoliya *et al.* (2015); Harish (2009). Higher accumulation of dry matter content in fruits grown with the application of 10% *Enriched Sanjeevani* (T_2), resulting from greater availability of plant nutrients under the influence of better microbial activity might probably be the cause of the higher level of ascorbic acid content.

CONCLUSION

The findings revealed that organic intervention with the liquid organic formulation '*Enriched Sanjeevani*' to its 10% concentration in combination with vermicompost may be a suitable alternative to grow brinjal organically. Not only the growth and yield attributes of brinjal is enhanced with the application of that organic liquid manure but also the proximate quality parameters are also greatly influenced. Accordingly, among the varieties, V_3 (Swarna Shree) and V_7 (Swarna Shyamali) emerged as better-performing varieties in terms of growth and yield attributes. Though the proximate quality traits of the varieties performed independently among each other. The comparative analysis among treatments showed that *Enriched Sanjeevani* (T_2) is better in terms of expression of both yield and quality attributing traits. Hence an organic approach of growing brinjal varietieslike V_3 (Swarna Shree) and V_7 (Swarna Shyamali) using organic liquid manure *i.e.,* 10% *Enriched* Sanjeevani (T_2) may be recommended for the cultivation of brinjal in the eastern Indian plateau.

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CONSUMPTION OF COMMERCIALLY AVAILABLE VITAMIN D FORTIFIED FOODS AND SUPPLEMENTS AMONG MUSLIM WOMEN IN COIMBATORE CITY

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ABSTRACT

Vitamin D fortification is an effective method to address the burden of Vitamin D deficiency worldwide. The effectiveness of fortification greatly depends on the availability and consumption of fortified foods. Thus, the study aims to identify commercially available Vitamin D fortified foods and supplements and their consumption among muslim women in Coimbatore city. In a market survey of 76 stores, selected by random sampling, data on the availability of fortified foods, cost, type and quantity of Vitamin D were recorded. Muslim women (n=225) between the age of 20–45 years were selected as respondents. Details on their demographic profile, health status, knowledge of Vitamin D, and consumption of fortified foods were collected. The findings revealed that 76 Vitamin D fortified products were available. Among these products, cereals and eggs provided >30 percent RDA of Vitamin D. A positive correlation existed between Vitamin D content and cost (P<0.05). Awareness about Vitamin D was very low among the women (3.6% to 7.7%). A moderately significant (p=0.052) association was observed between availability and consumption. Hence, an increase in awareness to promote the consumption of commercially available fortified foods is essential to combat Vitamin D deficiency.

Keywords: Vitamin D deficiency, Muslim Women, fFrtified foods, Consumption, Awareness

INTRODUCTION

Vitamin D, a very essential micronutrient, has gained importance recently due to its role in the global pandemic in both developed and developing countries. Vitamin D Deficiency has been observed among the population irrespective of age, region, economic status, culture and race as the most undistinguished and under-treated public health issue (Schoor and Lips, 2011). This vitamin plays a vital role in calcium absorption and thereby maintenance of bone health and studies have shown the importance of Vitamin D in decreasing the risk of skeletal and muscular dysfunction (Hazell *et al*., 2012). The discovery of Vitamin D receptors has unfolded its role in infection, autoimmune

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disease, obesity, depression, cancer, diabetes mellitus and heart disease, which are a burden to the community and with an increase in Vitamin D deficiency could lead to adverse consequences (Aparna *et al*., 2018).

Though the main source of Vitamin D is from the skin exposure to UVB rays of sunlight, it can also be provided by food sources, fortified foods, dietary supplements and medicinal supplements. Production in the skin is found to be the major source of Vitamin D produced in the most recommended D3 form, followed by fortification of foods (Nair and Maseeh, 2012). Even though sunlight is abundantly available in India, the presence of Vitamin D deficiency is still prevalent among the population, since the production of Vitamin D in the skin is affected by factors such as age, the colour of skin, latitude, altitude, season, time of the day, the extent of skin covering and environmental pollution (William *et al*., 2011). Every individual can be characterized as Vitamin D sufficient or deficient based on their serum 25 OH Vitamin D levels (Zhao *et al*., 2017). Very few food sources rich in Vitamin D such as oily fish, mushrooms, cod liver oil, beef liver, etc. are present which cannot be entirely dependent to combat Vitamin D deficiency.

Muslim women around the world follow a unique lifestyle influenced by their culture including Islamic dress codes, an indoor lifestyle and distinctive dietary patterns, these practices may affect the Vitamin D status of these Women (Mutair *et al*., 2014).Earlier research has revealed a high prevalence of Vitamin D deficiency among the muslim women living in different parts of the world. As the lifestyle of the muslim women minimises sunlight exposure and low availability of Vitamin D rich foods, increasing intake of fortified foods may be considered to improve the Vitamin D status among these women (Ross *et al*.,2011). Fortification is a process (one among the strategies suggested by WHO and FAO) to prevent and control micronutrient malnutrition. While policies for Vitamin D fortification have has been set in developed countries such as Canada and the USA, in case of India regulations on Vitamin D fortification are yet to be enforced (Olson *et al*., 2021; Gupta, 2014). The effectiveness of fortification as a resolve to prevent Vitamin D deficiency depends on the availability, amount of fortification, attitude and consumption by the target population. Coimbatore city, the second-largest city in Tamilnadu has a sizeable Muslim population and is purposively selected. Hence, the study aims to find out the consumption of commercially available Vitamin D fortified foods and supplements among Muslim women in the Coimbatore city.

MATERIALS AND METHODS

A general survey not specific to any target group was conducted to ascertain the availability of Vitamin D fortified food and supplements in the local markets of Coimbatore city and online stores and to assess the consumption of Vitamin D fortified food intake among Muslim women. According to the Government of India (2011), 44,984 Muslim women reside in Coimbatore city. A qualitative survey of the local market aiming to collect data on the availability of Vitamin D fortified foods in the local market of Coimbatore city was conducted between December, 2018 and March, 2019 using a specially designed list item form for collecting data on shop name, type of shop, fortified product name, company, quantity and form of Vitamin D fortification and cost of the product. The survey used random sampling method for the selection of shops, and hence, prior permission was obtained from the shop owners for participation. The randomly selected shops were classified into petty shops, grocery stores, departmental stores and online stores based on the Indian classification of retail outlets (Jagdish *et al*., 2013). Data was collected from the food labels of the products and the required details were recorded. A total of seventy-six shops including 29 grocery stores, 25 petty shops, 15 supermarkets and seven online stores were surveyed. Care was taken to identify the repetition of products and there was no new product identified in the last 10 shops surveyed.

A total of 225 Muslim women between the age group of 20 – 45 years were selected as a sub-sample by purposive sampling method to identify the Vitamin D fortified food consumption. Details on age, socio-economic status, education, occupation, knowledge, attitude, consumption and frequency of consumption of Vitamin D fortified foods were collected with the help of an interview schedule. Ethical approval was obtained from the Institutional Human ethical committee certificate no.: AUW/IHEC-18-19/FSN/FHP-08 and from the local Jamad Head. Written consent was obtained from the muslim women before data collection. The collected data were consolidated and statistically analysed using SPSS software version 2.0. Descriptive statistics such as frequency, mean and standard deviation were calculated. Correlation and Multiple linear regression were used to compare the variables.

RESULTS AND DISCUSSION

Market survey on the availability of Vitamin D Fortified products

A total of 76 food products including fortified foods and dietary supplements were identified from the market survey conducted in petty shops, grocery stores, departmental stores of Coimbatore city and online stores. The food products fortified with Vitamin D categorised into four different types: food products fortified with Vitamin D, Vitamin D2, Vitamin D3 and fortified with both Vitamin D2 and D3, respectively. Among the fortified products, 69.7 percent of the products did not have a specification on the type of Vitamin D fortification, while 25 percent fortification was in the form of Vitamin D2 with only 3.9 percent fortified with D3 and 1.4 percent fortified with both forms of vitamin D (Fig. 1) Literature review has suggested fortification with Vitamin D3 to be more effective to increase serum 25(OH) Vitamin D levels compared to Vitamin D2 (Wilson *et al*., 2017). Thus, the low availability of Vitamin D3 fortified products observed in the local market survey may be an indicator of the low potential of commercially available fortified foods in preventing Vitamin D deficiency.

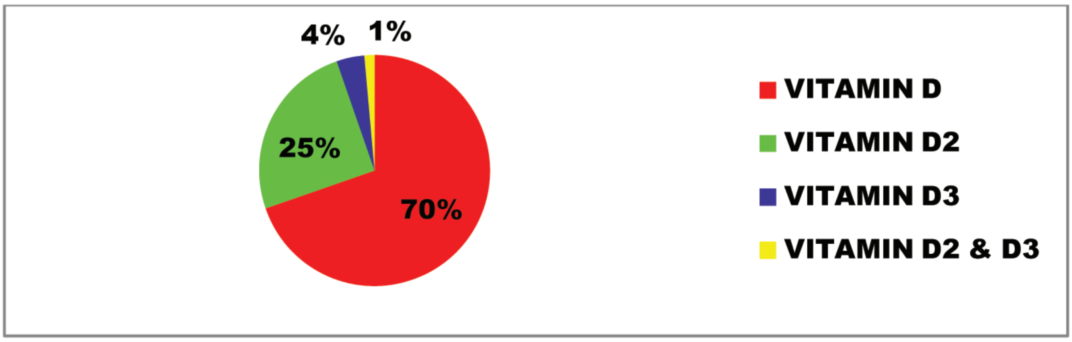
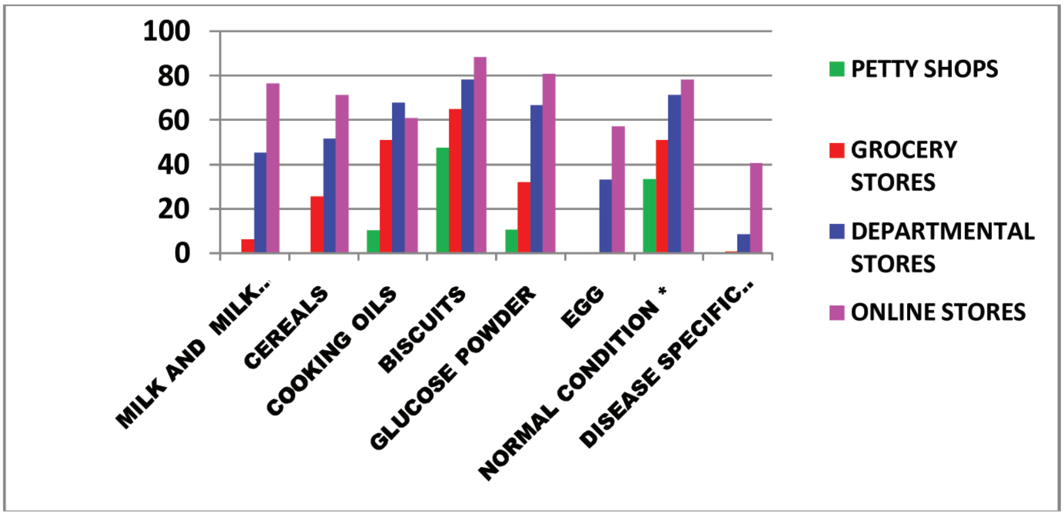


Fig 1. Different forms of Vitamin D fortification

Availability of Vitamin D fortified products in different shops and stores

A general market survey on Vitamin D fortified food products without any specific target group was conducted. The fortified foods and dietary supplements identified were under the group's milk and milk products, cereals, cooking oil, biscuits, glucose powder, eggs and dietary supplements for normal condition and disease specific (Fig. 2). The availability of these products was high in online stores followed by departmental stores. Among the fortified products, the mean availability of Biscuits(48 %) and regular dietary supplements (33.5 %) was the highest in petty shops. In the other three outlets, the availability of biscuits was 65 to 88 percent, cooking oil was 51 to 68 percent and regular dietary supplements were 51 to 78 percent. Milk and milk substitutes, eggs, cereals, glucose powder availability was considerable only in departmental stores and online stores. Disease specific supplements such as D - protein, Mildrich D, ensure DM, Pro360 nephro LP, nephro HP, etc. was found to be 40 percent accessible from online stores.



*Supplements

Fig. 2. Availability of Vitamin D fortified products in different shops and stores

Table 1 represents the number of fortified food products and dietary supplements identified under each group and their percentages, mean Vitamin D content and cost of products under each group per 100 g. On comparison of the mean quantity of Vitamin D fortification per 100 g of the product under each group with Recommended Dietary Allowance (RDA) for adults which is 15 mcg as per the Indian Council of Medical Research (2020). Cereals (32%) and eggs (100%) can be used effectively to boost Vitamin D levels when compared with products such as cooking oil, glucose powder, and dietary supplements. Though a considerable amount of Vitamin D was present in these products the portion size of consumption is limited to 20– 30g. Milk and milk substitutes and biscuits contributed only 12 -15 percent per 100 g of the daily requirement. Hence, it might be concluded that less Vitamin D will be obtained from these

Table 1. Vitamin D content and cost of the Fortified product

Products	Number (%)	Mean Vitamin Dfortification mcg/100g	Perce-ntage of RDA*	Cost of the product (Rs./100g)	Association Between Vitamin D content and cost
Foods					
Milk and Milk	11(10.2)	1.85 ± 2.7	12.4	14.06 ± 13.0	
Substitutes Cereals	4(3.7)	4.72 ± 0.9	31.5	55.96 ± 15.6	
Cooking oil	18(16.7)	9.35 ± 3.2	62.4	18.26 ± 4.34	0.036**
Biscuits	11(10.2)	2.33 ± 1.8	15.5	14.01 ± 3.9	(p <0.05)
Glucose powder	3 (2.7)	13.5 ± 5.2	90	46.73 ± 31.7	
Egg	1(0.9)	15 ±0	100	12 ± 0	
Dietary Supplements					
Normal condition	21 (19.4)	7.47 ± 4.9	49.8	82.12 ±42.2	0.907
Disease specific	7 (6.5)	4.96±1.4	33.1	168.3 ± 49.1	(p>0.05) NS

*ICMR, 2020; **Significant at 5% level, NS – Non Significant

products. A positive significant relationship was observed between fortified Vitamin D content and the cost of the products in the food group ($p<0.05$). On the contrary, among dietary supplements the relationship between fortification and cost was not significant. A similar increase in cost based on an increase in Vitamin D content has been observed in a study on medicinal supplements (Gupta, 2014).

Demography and Consumption of Vitamin D fortified Foods among the muslim Women

Muslim women with their unique lifestyle and culture may be prone to Vitamin D deficiency. Vitamin D fortified foods may be considered a better source for these women to correct the deficiency (Shakir, 2012). In the study, 225 muslim women were selected of which 46 percent were in the age group of 20 to 29 years, 29 percent fell under 30 to 39 years age group and the remaining 25 percent belonged to 40 to 45 years. A total of seventy-nine percent of the families belonged to high income group (> Rs.14,500/ month) as per HUDCO classification (Achal Gupta, 2008)) implying higher purchase capacity among muslim women. Overall, 65 percent of the women were housewives. In the age group of 20 -29 years, 51.9 percent of them were graduates, while in the other two age groups primary education was predominant category(> 51%).

Table 2 reveals that the knowledge on Vitamin D fortified foods was 3.6 to 7.7 percent among Muslim women, which was lower than 29 percent observed in the study evaluating the knowledge on fortified foods in pregnant women (Kasankala *et al.*, 2018) Consumption of fortified

Table 2. Consumption and purchase of Vitamin D fortified foods among the muslim women (n = 225)

Constructs/Items	**20–29 yrs, n =104(%)**	**30–39 yrs, n =66 (%)**	**40–45 yrs, n =55(%)**
Knowledge on basics of fortification	8(7.7)	4(6.1)	2(3.6)
Attitude towards fortified foods	75(72.1)	60((90.9)	49(89.1)
Consumption of Vitamin D fortified food	7(6.7)	7(10.6)	5(9.1)
Reason for not consuming			
Not aware	96(92.4)	57(86.4)	49(89.1)
Not available	1(0.9)	2(3.0)	1(1.8)
Place of Purchase			
Petty shops	28(26.7)	27(40.9)	20(36.4)
Grocery stores	61(58.7)	32(48.5)	34(61.8)
Departmental stores	55(52.8)	32(48.5)	19(34.5)
Online stores	4(3.8)	2(3.0)	1(1.8)

foods was as low as only 6 % to 10%. The main reason specified was lack of awareness about Vitamin D fortified foods. The attitude towards consumption is 72 % to 90 % in all the age groups but the low consumption might be due to a lack of awareness. Women in all three age groups purchased in grocery stores (48.5% to 61.8 %) followed by departmental stores (34.5% to 52.8 %).This indicated better access to Vitamin D fortified foods in their neighborhood but the online purchase was very limited (1.8 % to 3.8 %).

Data on the frequency of fortified food consumption revealed that a daily intake of cooking oil was found among 54.7 percent of the muslim women with a mean consumption of 16.42 ml. Consumption of fortified milk was 6.2 percent and mean consumption among the muslim women was 192.8 ml. The consumption of dietary supplements was 3.5 percent every week, consumption of fortified cereals was very negligible (1.3 %) and 20 percent of fortified biscuits were consumed daily and weekly.

Association between awareness, consumption and availability

Table 3 depicts the scores that were provided based on questions on awareness and consumption-based frequency of intake for all the 225 muslim women. The availability was categorized based on their source of purchase. Using multiple linear regressions, the association of consumption with awareness and availability was analysed.

There was no significant association observed at $p<0.05$, However, the significance value for awareness and consumption was 0.052 denoting awareness to be a marginally positive

Table 3. Association between awareness, consumption and availability

Variables	Consumption		
	Regression coefficient (â)	Standard error	Significance (p)
Awareness	0.16	0.08	0.052(NS)
Availability	0.02	0.06	0.771(NS)

NS – Not Significant

predictor of consumption among Muslim women. There was no association between the availability of fortified foods in the source of purchase and consumption among the women.

CONCLUSION

The bioavailability of Vitamin D fortification could not be ascertained as in the majority of products the form of fortification was not specified. The purchase from the departmental stores among the women was higher complementing with the availability of Vitamin D fortified products which suggests greater access to fortified products. Due to low Vitamin D3, fortified products bioavailability was low. The food products fortified were 47 products and Vitamin D fortification was very low in the range of 0.003mcg to 16.5 mcg per 100g. Considering the amount of fortification and portion size, cereals and eggs may be suggested as better sources among fortified foods. The association of cost with the amount of fortification raises concern as an increase in the amount of fortification may also affect the purchasing capacity. A moderately significant association between awareness of Vitamin D fortification and consumption of Vitamin D fortified products was observed in the study. Hence, creating awareness by nutrition communication in the community, in social media and advertisements may help in improving the consumption of Vitamin D fortified foods and thereby reduce the risk of Vitamin D deficiency among Muslim Women.

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STANDARDISATION AND QUALITY EVALUATION OF FRUIT PULP BASED YOGHURTS

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ABSTRACT

Nutritious and palatable yoghurts with diversified flavours were prepared by adding sapota and guava fruit pulps. Incorporation of 10-20% fruit pulp has imparted acceptable organoleptic qualities to yoghurts, with the moisture, pH and total acidity levels unaltered. During fortnight storage, the water holding capacity of sapota pulp-based yoghurt has only slightly changed from 50.46% to 53.00% whereas, it was 50.34% to 52.80% in guava pulp-based yoghurt. Syneresis initiated on the tenth day of storage was at 0.5% and 1.0% level in the fruit pulp-based yoghurts and plain yoghurt, respectively, which increased to 0.6% and 1.02% on fifteenth day. Energy and fat contents were higher in plain yoghurt. Fruit yoghurts were found to have higher amounts of â carotene, vitamin C, iron and potassium compared to the plain yoghurt. Thus, the enrichment with sapota and guava pulps made the yoghurts healthier and opened the possibility for product diversification.

INTRODUCTION

Yoghurt is an acidified, custard like semi-solid dairy product developed by fermenting pasteurised milk with starter culture containing a synbiotic blend of *Streptococcus thermophilus* and *Lactobacillus delbruckii* sub spp*. Bulgaricus* (Vasiljevic and Shah, 2008). Yoghurt is well known for its nutritional value, therapeutic effects and functional properties and is an excellent source of protein, calcium, potassium, vitamin B_2, B_6, and B_{12} (Wang *et al*., 2013). Yoghurt is easily digested, has high nutritional value, and is a rich source of carbohydrates, protein, fat, vitamins, calcium and phosphorus. Its effectiveness against curing diarrhoea, dysentery, constipation, high blood cholesterol and carcinogenesis are known (Roy *et al*., 2015).

Yoghurt is a safer product with unique flavour and consumer preference. Hence, consideration is given by nutritionists to incorporate inexpensive source of nutrients to make it an almost complete food. Fruits and vegetables are rich sources of vitamins, minerals, fibres and antioxidants, therefore, can be used in making value added products. Fruit yoghurts is widely popular due to its partially masked acetaldehyde flavour compared to plain yoghurt. A fruit concentration of 5% to 15% is

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recommended for making fruit yoghurts (Farahat and Bataway, 2013).

MATERIALS AND METHODS

Collection of raw materials:Standardised milk with fat and SNF content of level of 3.5 and 8.5%, respectively were found to be best for the preparation of yoghurt. The cultures *Lactobacillus bulgaricus*and *Streptococcus thermophilus*required for the study were purchased from College of Dairy Science and Technology, Kerala Veterinary and Animal Sciences University (KVASU), Thrissur, India. The study was conducted in the Department of Community Science, College of Agriculture between 2018 and 2020.

Optimization of fruit pulps: The fruit pulp was filled in conical flasks and then pasteurized at 70^0 C for 30 seconds. The milk was pre-heated to 55^0 C and 1.0% skimmed milk powder and 6.0% sugar were added. It was then pasteurized, cooled to 55^0C and fruit pulp added. At 42^0C, the mixture was inoculated with 2% yoghurt culture, gently homogenized and incubated for 4 h in an incubator to maintain the temperature. Subsequently, the yoghurts werepacked in food grade containers and refrigerated at 4Ë%C.

The treatments used for standardization of fruit pulp-based yoghurts includedT_0/Control: M 100% (plain yoghurt), T_1: M 90% + SP 10%, T_2: M 85% + SP 15%, T_3: M 80% + SP 20%, T_4: M 75% + SP 25%, and T_5: M 70% + SP 30%, in which, M - milk and SP - sapota pulp. Experiments were repeated by substituting sapota pulp with guava pulp.

Organoleptic evaluation: Organoleptic evaluation of fruit pulp-based yoghurts including control was conducted by using score cards by a panel of 20 judges. Based on the organoleptic scores, the best treatments most suitable for yoghurt with sapota pulp and guava pulp were selected for further studies.

Physicochemical properties: Moisture, acidity,pH content,water-holding capacity of fruit pulp-based yoghurts were estimated by standard procedures. Spontaneous syneresis and curd tension of undisturbed set curd was determined using siphon method. Total Soluble Solids, total sugar, reducing sugar, energy, carbohydrate, lactose, protein, fat, â carotene, vitamin C, calcium and iron were also determined using standard procedures.

RESULTS AND DISCUSSION

Yoghurt prepared using cow milk (control) got the highest score for all sensory attributes. The total score attained for control was 52.57 and 52.23 for sapota and guava pulp, respectively.Among different treatments tried for the preparation of sapota and guava pulp-based yoghurts the highest score was attained for the fruit yoghurts prepared using 90% milk and 10% fruit pulp. Yoghurt flavoured with orange juice was preferred over plain yoghurt (Ozdemir *et al.,* 2005). In the study,maximum organoleptic scores were attained for plain yoghurts when compared to fruit yoghurts (Table 1).

Changes in the physico-chemical properties of yoghurts with the days of storage are shown in Table 2. The initial moisture content of sapota yoghurtand guava yoghurtwas found to be 79.58% and 79.40% respectively. A decreasing trend in moisture content with storage was observed for all treatments. Sarabhai (2012) also reported a decrease in moisture content during storage of yoghurts. Warakaulle *et al.* (2014)

observed 79.37% moisture content in plain cow milk yoghurt and 79.35% moisture content in water melon enriched yoghurt. Amal *et al*. (2016) observed 87.64% moisture content in papaya yoghurt and 84.79% were found in cactus pear added yoghurts.

According to Tamime and Robinson (1999), a typical full fat yoghurt and fruit yoghurt should contain 81.9% and 77.00% moisture, respectively. This is in line with the result of this study.

Compared to fruit yoghurts pH value of control was found to be slightly higher than both sapota and guava pulp-based yoghurts throughout the storage period. The pH of 4.6 was reported to be optimum level for production of good quality yoghurts. This is in line with the present study in which the pH was in the range of 4.52 to 4.47.

Celik *et al*. (2006) also observed continued decrease in pH of the plain yoghurt and fruit yoghurts during storage. The decrease in pH can be attributed to the fermentation of sugar and the presence of lactic acid producing organisms. When, the sugar sources exhaust, microorganisms begin to consume proteins and the metabolites formed by microbial activity could increase the pH of the product (Tapsoba*et al*., 2014). The pH is inversely proportional to the acidity of products. The pH of yoghurts with storage, leads to an increase in acidity. Lactic acid produced during fermentation can increase the acidity or decrease the pH. In this study, also the acid content increased with storage. Results were also recorded by Amal *et al.* (2016).

The initial acidity of plain yoghurt was 0.68 which increased with every five days of interval, it reached up to 0.76 on 15 days of storage. Control yoghurt exhibited the highest value for acidity. Amal *et al*. (2016) reported that acidity was increased during storage period in papaya and cactus pear pulp added yoghurt. Sarabhai (2012) reported that acidity was increased throughout the storage period.

The water holding capacity in yoghurt determines the microstructure of the protein network. If the water binding is not sufficient, whey will be expelled on the surface of the product during storage (Mortensen *et al*., 2005). Initial water holding capacity of plain yoghurt was 47.30 and for T_1 and T_2 it was 50.46 to 50.34. An increased trend in water holding capacity was observed in all yoghurt samples. Lower WHC or whey separation refers to a weakness of gel network (Singh and Muthukun, 2008). Amal *et al*. (2016) also observed an increase in WHC throughout the storage period. The WHC of cactus pear yoghurt was found to be higher than that of papaya yoghurt.

The maximum curd tension was noticed in plain yoghurt which varied from 54.00 (initial) to 60.00 (15 days). Curd tension of sapota yoghurt and guava yoghurt,varied from 38.60 to 45.60 and 38.66 to 54.66 from the initial to 15th day of storage. El-Boraeyet *et al*. (2015) reported the curd tension of cow milk as35.41 in freshly prepared yoghurts and 36.15 after 7 days of storage. A high curd tension of 70.87 was observed in the yoghurt prepared with buffalo milk. Chaudhari *et al.* (2007), reported the average curd tension in *dahi*prepared from buffalo milk was higher (43.44) than *dahi* prepared from cow milk (34.94). Increase in curd tension, helps to overcome wheying off with improvement in viscosity and consistency.

Syneresis is collection of whey from yoghurt and is the key quality parameter for yoghurt. Higher level of syneresis shows that yoghurt is of low quality. No syneresis was observed till 5th day of storage for both plain and fruit pulp-based yoghurts. Syneresis of 1.0% and 1.02% were observed on the 10th day and 15th day of storage in plain yoghurts. In sapota and guava yoghurts, a syneresis level of 0.5 and 0.6% were detected on the 10th and 15th day of storage. Syneresis level of 1.10% was noticed by Sarabhai (2012) in plain yoghurt. Joon *et al*. (2017) found that yoghurts from goat milk revealed the higher syneresis (9.92±0.02), whereas, yoghurt from cow milk was found to be the lowest (9.65±0.03). The major visible defect occur during yoghurt storage and can affect the final product acceptance. Syneresis occurs due to the loss of yoghurt gel capacity to entrap serum phase through the weakening of the gel network resulting on whey separation.

Changes in the nutritional content of yoghurts with the days of storage are presented in Table 3. The control yoghurt had a TSS content of 14° Bx (initial) to 13.24° Bx (15th day). The TSS content was found to be higher than plain yoghurt and the gradual decrease was noticed throughout the storage period. The TSS content of sapota and guava yoghurts reduced to 15.10 and 13.99, respectively at the end of storage. Compared to control, fruit yoghurts had higher reducing and total sugar content. Kale *et al*.(2008) prepared pomegranate yoghurt with reducing sugar content of 5.67%.

Lactose content of yoghurt is comparatively low than that of milk. Fruit yoghurts showed significant decrease in lactose content. In control (plain yoghurt) the lactose content ranged between 2.94% to 2.82%. Hassan and Amjad (2010) reported that average lactose value of *L. bulgaricus* yoghurt was 5.21% while that of *L. acidophilus* yoghurt was 4.61%.

Protein content decreased significantly in all samples during storage. As per FSSAI (2011) regulations milk yoghurt should contain 3.2% milk proteins and for fruit yoghurts it is 2.6%. The fat content in all freshly prepared yoghurts was above 1.02 g, and decreasing trend of fat was observed in every five days interval. A decrease in fat content during storage which is due to lipolytic activity of enzymes lipase and lipoxidase produced by microorganisms.

Vitamin C content of fruit yoghurts were found to be higher than that of plain yoghurt. Addition of fruit pulp increased the vitamin C content. The addition of water melon juice into yoghurt resulted in an increase in vitamin C content (Warakaulle *et al*., 2014). Calcium content of FPBY were low when compared to control yoghurt. Fruit yoghurts had a slightly higher value for iron and potassium content compared to control yoghurt.

CONCLUSION

Fruits such as sapota and guava can be used for fruit yoghurt preparations. Incorporation of 10% fruit pulp attained the maximum organoleptic scores for both sapota pulp-based yoghurt and guava pulp-based yoghurt. It was also found that incorporation of 20% fruit pulps will give acceptable products. Moisture, pH and acidity of fruit pulp-based yoghurts was on par with plain yoghurt. An increase in water holding capacity and curd tension with storage were observed in all yoghurts. Syneresis was not observed till 5th day of storage, and on 15th day,

Table 1. Mean score for organoleptic qualities of sapota and guava yoghurt

Treatments	Milk: Fruit pulp	Appe-arance	Color	Flavour	Taste	Text-ure	Overall accep-tability	Total score
T_0	100:0	8.84	8.75	8.64	8.86	8.80	8.68	52.57
SP		8.37	8.93	8.88	8.71	8.77	8.57	52.23
T_1	90:10	8.66	8.57	8.46	8.66	8.35	8.53	51.23
SP: GP		8.97	8.06	8.08	8.91	8.26	8.06	50.34
T_2	85:15	8.46	7.93	8.26	7.91	7.71	7.86	48.13
SP: GP		7.73	7.73	7.48	7.42	7.37	7.46	45.19
T_3	80:20	7.62	7.24	8.02	7.46	7.42	7.46	45.22
SP: GP		7.31	7.31	7.00	6.84	7.24	7.02	42.72
T_4	75:25	6.91	6.86	7.53	6.64	6.73	6.42	41.09
SP: GP		6.95	6.91	6.26	6.48	6.57	6.91	40.08
T_5	70:30	6.40	5.60	6.77	6.35	6.02	6.28	37.42
SP: GP		6.35	5.73	6.33	5.77	6.42	5.93	36.53
Kendall's (W)		**0.928**	**0.895**	**0.810**	**0.919**	**0.939**	**0.940**	**5.431**
		0.989	**0.986**	**0.985**	**0.968**	**0.959**	**0.972**	**5.859**

Table 2. Changes in the physico-chemical properties of yoghurts with the days of storage

Treatments	Day of storage			
	0	5	10	15
Moisture (%)				
T_0 (Control)	78.05	75.01	72.11	70.00
T_1 (SPBY)	79.58	76.03	74.56	72.07
Treatments	**Day of storage**			
	0	**5**	**10**	**15**
T_2 (GPBY)	79.40	76.00	74.22	73.04
pH				
T_0 (Control)	4.52	4.41	4.36	4.27
T_1 (SPBY)	4.68	4.53	4.43	4.37
T_2 (GPBY)	4.57	4.42	4.35	4.15

Table 2 Contd.

Treatments	Day of storage			
	0	5	10	15
Acidity (%)				
T_0 (Control)	0.68	0.70	0.72	0.76
T_1 (SPBY)	0.61	0.63	0.64	0.65
T_2 (GPBY)	0.60	0.65	0.77	0.89
Water holding capacity (%)				
T_0 (Control)	47.30	50.25	52.20	53.66
T_1 (SPBY)	50.46	51.72	52.60	53.00
T_2 (GPBY)	50.34	51.11	52.10	52.80
Curd tension (%)				
T_0 (Control)	54.00	54.11	56.70	60.00
T_1 (SPBY)	38.60	41.00	43.00	45.60
T_2 (GPBY)	38.66	40.11	42.11	45.66
Syneresis (%)				
T_0 (Control)	ND	ND	1.00	1.02
T_1 (SPBY)	ND	ND	0.5	0.6
T_2 (GPBY)	ND	ND	0.5	0.6

SPBY: Sapota pulp-based yoghurt; GPBY: Guava pulp-based yoghurt

0.6 and 1.0% were observed in fruit pulp-based and plain yoghurt, respectively. The TSS, total sugar, reducing sugar, carbohydrate and lactose content were similar in all the yoghurts till the 15th day of storage.Yoghurt with cow milk had higher energy and fat content than sapota and guava yoghurts. Fruit yoghurts were found to have higher amounts of â carotene, vitamin C, iron and potassium compared to the plain yoghurt. Thus, the enrichment with sapota and guava pulp made the yoghurts enriched with micronutrients making it healthier and product diversification using fruits.

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Table 3. Changes in thenutritional content of yoghurts with the days of storage

Treatments	Day of storage			
	0	5	10	15
Total Soluble Solids				
T_0 (Control)	14.00^{NS}	13.87^{NS}	13.53^{NS}	13.24^{NS}
T_1 (SPBY)	16.00^{NS}	15.76^{NS}	15.43^{NS}	15.10^{NS}
T_2 (GPBY)	15.00^{NS}	14.56^{NS}	14.21^{NS}	13.99^{NS}
Total sugar (%)				
T_0 (Control)	11.88^{NS}	11.82^{NS}	11.77^{NS}	11.71^{NS}
T_1 (SPBY)	15.14^{NS}	15.11^{NS}	15.01^{NS}	14.94^{NS}
T_2 (GPBY)	14.14^{NS}	14.10^{NS}	14.07^{NS}	14.02^{NS}
Energy (Kcal))				
T_0 (Control)	82.68^{a}	72.68^{b}	63.32^{c}	55.20^{d}
T_1 (SPBY)	73.54^{a}	68.52^{b}	61.95^{c}	50.35^{d}
T_2 (GPBY)	55.72^{a}	50.24^{b}	44.13^{c}	37.65^{d}
Carbohydrate (%)				
T_0 (Control)	11.5^{NS}	11.00^{NS}	10.58^{NS}	10.00^{NS}
T_1 (SPBY)	10.6^{NS}	10.10^{NS}	9.80^{NS}	9.40^{NS}
T_2 (GPBY)	8.0^{NS}	7.50^{NS}	7.20^{NS}	6.00^{NS}
Lactose (%)				
T_0 (Control)	2.94^{NS}	2.90^{NS}	2.86^{NS}	2.86^{NS}
T_1 (SPBY)	2.72^{NS}	2.68^{NS}	2.65^{NS}	2.62^{NS}
T_2 (GPBY)	1.44^{NS}	1.40^{NS}	1.37^{NS}	1.33^{NS}
Protein (%)				
T_0 (Control)	4.59^{NS}	3.88^{NS}	3.67^{NS}	3.35^{NS}
Treatments	**Day of storage**			
	0	**5**	**10**	**15**
T_1 (SPBY)	3.77^{NS}	3.57^{NS}	3.33^{NS}	2.71^{NS}
T_2 (GPBY)	3.23^{NS}	3.11^{NS}	3.00^{NS}	2.61^{NS}

Table 3 Contd.

Treatments	Day of storage			
	0	**5**	**10**	**15**
Fat (%)				
T_0 (Control)	2.8^{a}	2.00^{ab}	1.2^{b}	1.00^{c}
T_1 (SPBY)	1.02^{NS}	1.00^{NS}	0.55^{NS}	0.20^{NS}
T_2 (GPBY)	1.2^{NS}	1.00^{NS}	0.71^{NS}	0.51^{NS}
â Carotene (IU)				
T_0 (Control)	ND	ND	ND	ND
T_1 (SPBY)	1.29^{NS}	1.28^{NS}	1.27^{NS}	1.26^{NS}
T_2 (GPBY)	2.1^{NS}	2.00^{NS}	1.98^{NS}	1.96^{NS}
Vitamin C(mg/100g)				
T_0 (Control)	0.53^{NS}	0.53^{NS}	0.52^{NS}	0.51^{NS}
T_1 (SPBY)	0.76^{a}	0.74^{b}	0.73^{bc}	0.72^{c}
T_2 (GPBY)	0.85^{a}	0.82^{b}	0.80^{c}	0.75^{c}
Calcium (mg/100g)				
T_0 (Control)	78.00^{NS}			77.12^{NS}
T_1 (SPBY)	59.19^{NS}			59.00^{NS}
T_2 (GPBY)	61.24^{NS}			60.15^{NS}
Iron (mg/100g)				
T_0 (Control)	0.10^{NS}			0.10^{NS}
T_1 (SPBY)	1.24^{NS}			1.21^{NS}
T_2 (GPBY)	0.49^{NS}			0.47^{NS}
Treatments	**Day of storage**			
	0	**5**	**10**	**15**
Potassium (mg/100g)				
T_0 (Control)	60.01^{NS}			59.50^{NS}
T_1 (SPBY)	72.06^{NS}			72.01^{NS}
T_2 (GPBY)	74.03^{NS}			73.09^{NS}

5% significant level; Values having different superscripts differ significantly in DMRT, Minerals were estimated only in the initial and 15th day

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TRENDS AND PATTERNS OF DRY SPELLS IN KARNATAKA

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ABSTRACT

Drought affects agricultural growth by its duration and frequency. Karnataka an agrarian-based economy, experienced frequent intense droughts in the last two decades. This study analyzed the intensity and duration of dry spells that occurred in Karnataka between 1990 and 2020 in the spatial context by using SPI. The Standardized Precipitation Index (SPI) helped in identifying four significant drought incidents in the last three decades. Mann-Kendall Test was used to identify the trend in the SPI values. The results showed that the droughts in last decade were more intensive compared to previous two decades. The duration of recent dry spells got overlapped between two different drought periods. The northern districts of State get more frequent dry spells compared to the southern districts.

Keywords: Drought, El Niño, Spatial Analysis, SPI, South-West Monsoon.

INTRODUCTION

Drought affects agricultural growth by its duration and frequency. Karnataka an agrarian-based economy, experienced frequent intense drought in the last two decades. Drought for any region is determined by the degree of the lack of rainfall. A drought event gets terminated by an increase in precipitation. Karnataka has the second largest arid region of India; its dry zones spread from the northern to the southern side. The monsoon rainfall is the main source for irrigation and recharge of groundwater. In the last two decades, the state suffered from numerous severe drought incidences causing an adverse impact on the agriculture sector. Karnataka State Natural Disaster Monitoring Centre (KSNDMC) publishes annual rainfall report. KSNDMC Annual Report - 2020 and KSNDMC Annual Report - 2019 showed that most of the northern and few southern districts faced severe droughts in 2019 and 2018, respectively. Indian Meteorological Department (IMD) defines the meteorological drought for a region when the seasonal rainfall received is less than 75% from its long-term average value. IMD predicts the normal and deficient rainfall conditions which help agriculturists to deal with seasonal dry spells. But drought's duration and intensity could not be anticipated, and adelayed realization of drought could lead to crop failure, cattle deaths, emptied reservoirs, and mass migration of laborers (Rajendran, 2001). Besides

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natural variability in rainfall, anthropogenic factors such as concretization of urban and rural areas, excessive bore well usage, conversion of wetlands, encroachment of ponds and lakes, increased deforestation create groundwater and surface water shortages.These shortages could compound the impacts of drought on the economy through food production and supply shocks, increase in prices. The resultant famine condition could lower economic growth significantly through multiplier effects on other sectors as well.Droughts could result in a range of ecological impactsfromsoil infertility to desertification (Shewale and Kumar, 2005). From the purview of sustainable development goals, drought seems like an insidious natural disaster whose trend analysis can help in solving global issues. The objective of this work is to statistically analyze the drought periods in Karnataka for the period of 1990-2020 and trace their intensities' relevance to ENSO(El Niño-Southern Oscillation) pattern. The Standardized Precipitation Index (SPI) is used to identify dry and wet conditions. Mann-Kendall Test (2002) was used to identify the trend in the SPI values.The spatial analysis of SPI values is done to show the duration, intensity, and frequency of dry spells.

MATERIAL AND METHODS

The rainfall data utilized in this study is collected from IMD Hydromet Division and ICRISAT's District Level Dataset (DLD) in the year 2021. The dataset utilized for dry spells analysis is time series monthly rainfall data covering 30 districts of Karnataka for the period of 31 years from 1990 to 2020. The monthly rainfall amount is measured in millimeters.As perKöppen's classification, the state is divided into three climate zones (divisions) viz. coastal, north interior, and south interior.IMD and the Department of Agriculture define the climatic zones based on meteorological differences in districts' seasonal temperature and seasonal precipitation patterns.The state majorly relies on the South-West monsoon and gets a major share of annual rainfall in June, July, and August. However,IMD's reports show that the South Interior Karnataka gets enough share of rainfall from North-East monsoon as well. The mean and maximum rainfall for the state ranges from 1221 mm to 4370 mmin the studied time span (Fig. 1).

Indian monsoon conditions are linked with various climatic and weather phenomena such as ENSO (El Niño-Southern Oscillation), Indian Ocean Dipole conditions, Walker circulations, and surface temperature.ENSO (El Niño Southern Oscillation) is a Pacific ocean's climatic pattern that consists of three events: El Niño, Neutral phase, and La Niña. During El Niño phase,in the December month, the surface level water warms up more than usual in the eastern-central equatorial Pacific Ocean region.This warm wateraffects thermohalineocean circulation, change in trade wind speed and direction, surface air pressures, increased temperature in the sea surface. This weakens the intensity ofthe Indian Southwest monsoon. WhenEl Niño events vary between strong to moderate degrees,the southwest monsoon is weaker and provides below normal rainfall in India (Mooley and Parthasarathy, 1983). Kumar *et al.* (2006) observed that the central equatorial El Niño was more capable of creating drought situation over India than eastern equatorial El Niño. La Niña phase is coupled with cold events in the Pacific Ocean and generally strengthens the Indian monsoon conditions.The periodicity

Table 1. Classification of SPI values and their indications

S. No.	SPI Values	Dry/ Wet Conditions
1	2.0 and above	Extremely Wet
2	1.5 to 1.99	Severely Wet
3	1.0 to 1.49	Moderately Wet
4	-0.99 to 0.99	Near Normal
5	-1.0 to -1.49	Moderately Dry
6	-1.5 to -1.99	Severely Dry
7	-2.0 and below	Extremely Dry

Source: Standardized Precipitation Index User Guide, WMO

of these cycles is about 2 to 5 years and the meteorological impacts last more than a year. El Niño events of the last three decades were observed in this study. (Fig. 2, NOAA (2021)).

Incidence, intensity, frequency, and duration of meteorological drought could be measured by Standardized Precipitation Index (SPI) which is based on long-term precipitation in a region. The index calculates the deficit precipitation over different timescales desired such as monthly, quarterly, annual, etc. This study involves SPI in the 12-month timescaleto identify prolonged droughts. SPI value indicates deficit (by negative values) or excess (by positive values) in the rainfall, compared to the average rainfall level for a particular region in a particular month. The intensity of dry spellsis measured by the magnitude of the SPI value; a lower value indicatinga higher intensity of dryness. The drought event for an area is observed when SPI values are continuously negative and reach the level of -1 or less. Drought duration starts with the negative SPI value which showed deficit rainfall and ends with the positive SPI value (SPI User Guide, WMO).The SPI values are classified into different categories(Table 1).

The dataset is organized and analyzed with the help of R studio SPEI package and QGIS. SPI is calculated using the formula:

$$SPI = (P-P^*) / ó_p$$

in which, P = Precipitation, P* = mean Precipitation and $ó_p$ = standard deviation of precipitation.

Mann-Kendall (MK) test was used for analyzing drought trend in the districts over studied period. The test showed that there exist an upward trend of drought events in the state. However, few districts of North-Karnataka region had insignificant MK tau values.

RESULTS AND DISCUSSION

The district-wise analysis of annual rainfall distribution in the studied period showed that the northern interior region gets the minimum annual rainfall followed by the southern interior region. However, Shimoga, Chikmagalur, and Kodagu districts of the southern interior get higher rainfall compared to other districts of the zone. Dakshina Kannada and Udupi getthe maximum average annual rainfall in the State (Fig.1).

The results of this study indicated that in nearly 50% of the observed time, the study region had incidents of deficit rainfall;however, the quantum of the deficit is less and is closer to the normal value. Compared to the Southern interior zone, the Northern interior zone experienced dry spells that are predominantly higherin Intensity. Districts of Bidar, Chamarajanagara, Mysore, and Hassan showed the lowest SPI values among all the districts, indicating that these regions experienced intense dry spells compared to the rest of the districts (Fig. 1). It could be observed that there were around eight long-term drought incidents in the span of 31 years with four significant drought periodsin years of 1999-2005, 2011-2014, 2015-2018, and 2018-2020.

The first drought period (1999-2005) is significant in terms of its longer duration. During this period, Coastal districts experienced deficits in rainfall during the year 1999, while most districts faced deficits in the years 2000 and 2001. Dakshina Kannada, Uttara Kannada, and Udupi experienced deficient rainfall for as long as 70 months.Uttara Kannada experienced the most intense dry condition (-2.25 SPI value).The shortest dry spell of 19 months (-1.91 SPI value) was observed in Chamarajanagara.During this period, El Niño events of moderate (years 2002 and 2003) to weak (2004 to 2007) nature could be observed. Correspondingly, in the years 2002 and 2003, severely dry conditions prevailed in most of the districts (SPI values below -1.5). It could be observed that even in situations of weak or moderate El Niño events that continued for more than a year, the effect on monsoon conditions is considerable (Fig. 3).

Between the years 2008 to 2014, there was a continuous shift in ENSO pattern. In 2008, a strong La Niña event was there followed by two years extended moderate El Niño phase, and repeated La Niña events in 2011 and 2012. After this from the year 2014 onwards, weak to strong El Niño conditions were observed.

The second drought period (2011-14) was more prominent in South Interior Karnataka. The duration (months count) in this period was not as extended as during the previous period (years 1999-2005) but it did create extreme dry conditions for the Southern Region of the state. In this timeframe of 3.5 years, Mandya had experienced a continuous dry spell for 35 months (with up to -2.42 SPI value). Uttara Kannada had the shortest duration in this drought period, only for 11 months with moderately dry spells (Fig. 3). The years 2015 and 2016 were of strong El Niño conditions followed by weak La Niña from mid-2016 to mid-2018. Later, 2018-19 was observed as a year of weak El Niño. The consequence of such fluctuation could be observed on SPI values.

The continuous fluctuation of ENSO remained similar in the last five years as well; the only difference was in its intensity. In recent years, it was observed that the oceanic surface water gets much higher temperature during El Niño compared to previous events.

The third and fourth drought periods which were observed from 2015 to 2018 and 2018 to 2020 overlap for some districts. For most of the districts, the third drought period started from September 2015 and lasted upto September 2017 with the recorded least rainfall in July 2017. The third drought period(2015-2018) majorly affected the coastal region and central part of the state. This drought cycle was significant due to drought intensity.Dharwad, Gadag,Haveri, and Hassan experienced the longest dry spells with more than 30 months. Mysore, Chamarajanagara, Chitradurga, and Bellary recorded their lowest SPI value (below the limit of -3) in this period. The summer of 2017 observed an intense drought situation for all the districts; that was extremely dry for the south interior zone and severe dry for the north interior (Fig. 3). Majority of districts received average to above-average rainfall between October 2017 to August 2018.

The fourth drought period (2018-2020) was observed from September 2018 to September 2019 and peak negative SPI values were recorded in mid-2019. However, the third and fourth drought periods got overlapped for Bagalkote, Dharwad, Shimoga, Udupi, and Uttara Kannada. These districts had continuous negative SPI values from 2015 upto 2019; combined two drought periods these districts had the longest duration of dry spells that was around 50 months. On the other hand, for some districts, the fourth drought cycle lasted upto mid-2020. Bidar had the longest duration of continuous dry spells with more than 30 months and reached its lowest SPI value of -3.45 in this cycle. Few districts like Bangalore Rural, Mandya, Kodagu, and Ramanagara had no dry spells in this cycle. Districts whose dry spells overlapped with the third cycle experienced extremely dry conditions. (Fig. 3)

The dry spell counts out of 361 months were highest for Udupi and Uttara Kannada with 83 and 81 months, respectively. Whereas, the least count of dry spells was observed in Yadgir with only 37 months. As evident by the central region of the state, the average dry incident was 61 months(Fig. 4).

The dry spells are termed in three categories: moderately dry, severely dry, and extremely dry. The moderately dry spells were least frequent in Mysore with 18 incidents, while Uttara Kannada had a maximum of 74 incidents (Fig. 4).

The range of severely dry incidents in the studied period was 3 months to 33 months. Dakshina Kannada experienced most incidents of severely dry spells and Bidar had the least cases. The severely dry conditions were more prevalent in Southern Interior Karnataka (Fig. 4).

The state experienced many instances when extremely dry situations arose in the previous 30 years (showed by SPI value below -2). Bellary and Shimoga had suffered maximum times with extremely dry conditions. It must be noted that these two districts majorly rely on agriculture for economic revenue. In the studied period, Kolar never experienced any episodes of extremely dry spells. Uttara Kannada and Ramanagara experienced the least cases of extremely dry spells in the study period (Fig. 4).

It could be observed that the severe to extreme dry spells occurredduring El Niño events. Though the second and third drought periods were not concurrent to the respective year's ENSO pattern, it could be said that it was the consequence of previous El Niño cycles which were prevalent in 2009-2010 and 2014-2016. The coastal districts are majorly impacted due to ENSO pattern by way of long and intense drought periods.

CONCLUSION

This study analysed the frequency and duration of dry spells that occurred between

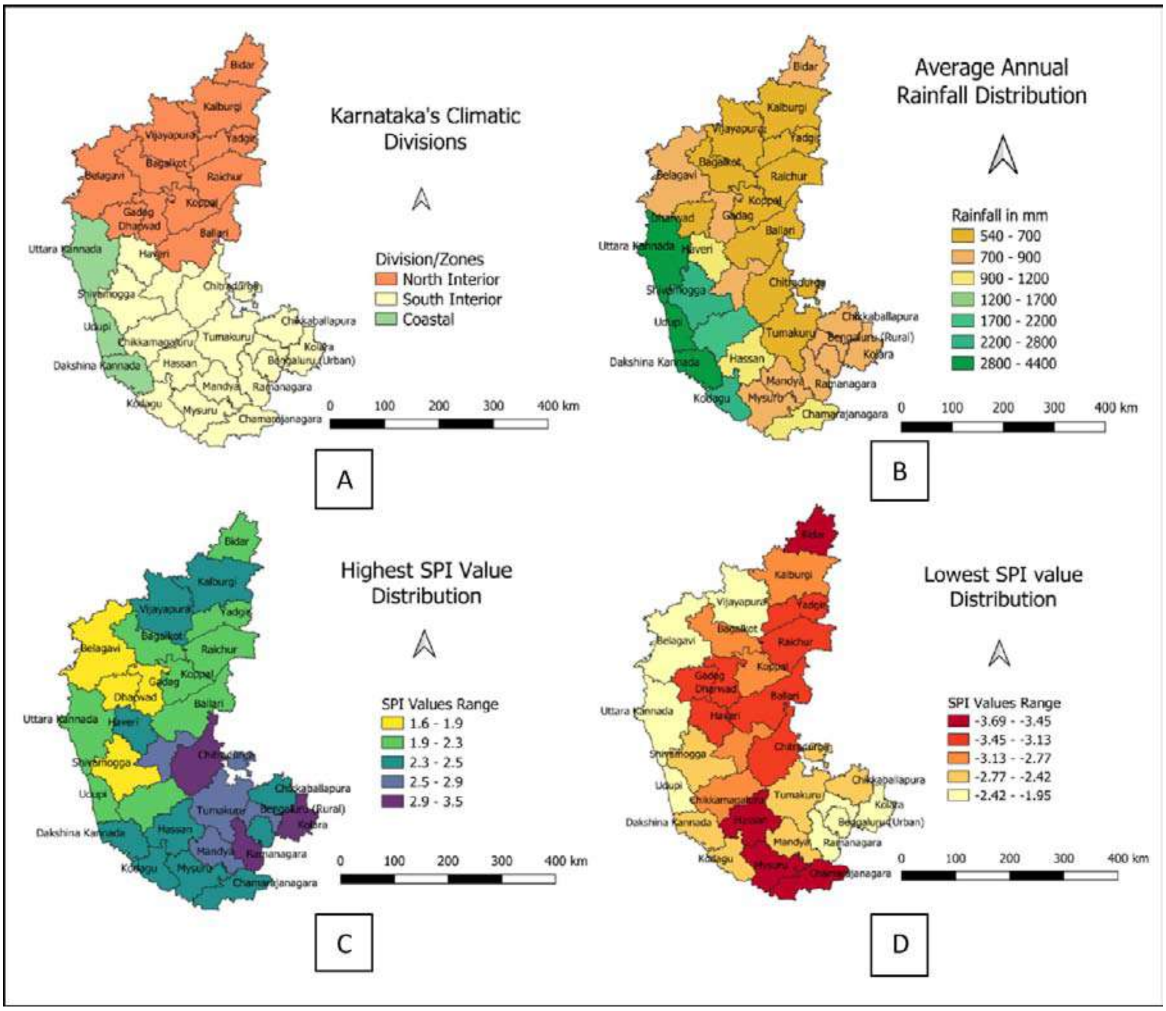
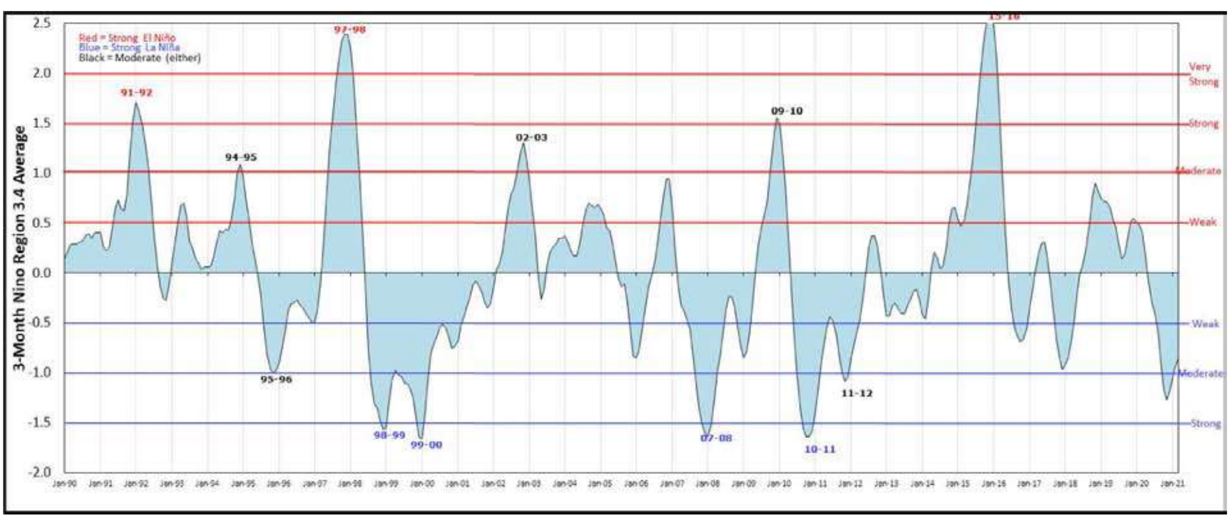


Fig. 1. Karnataka overview map with climatic region, average annual rainfall distribution, and SPI values distribution for the period of 1990-2020



Source: ncdc.noaa.gov (United States- National Oceanic and Atmospheric Administration)

Fig. 2. El Niño and La Niña events from 1990 to the present with the degree of events measured by Oceanic Niño Index

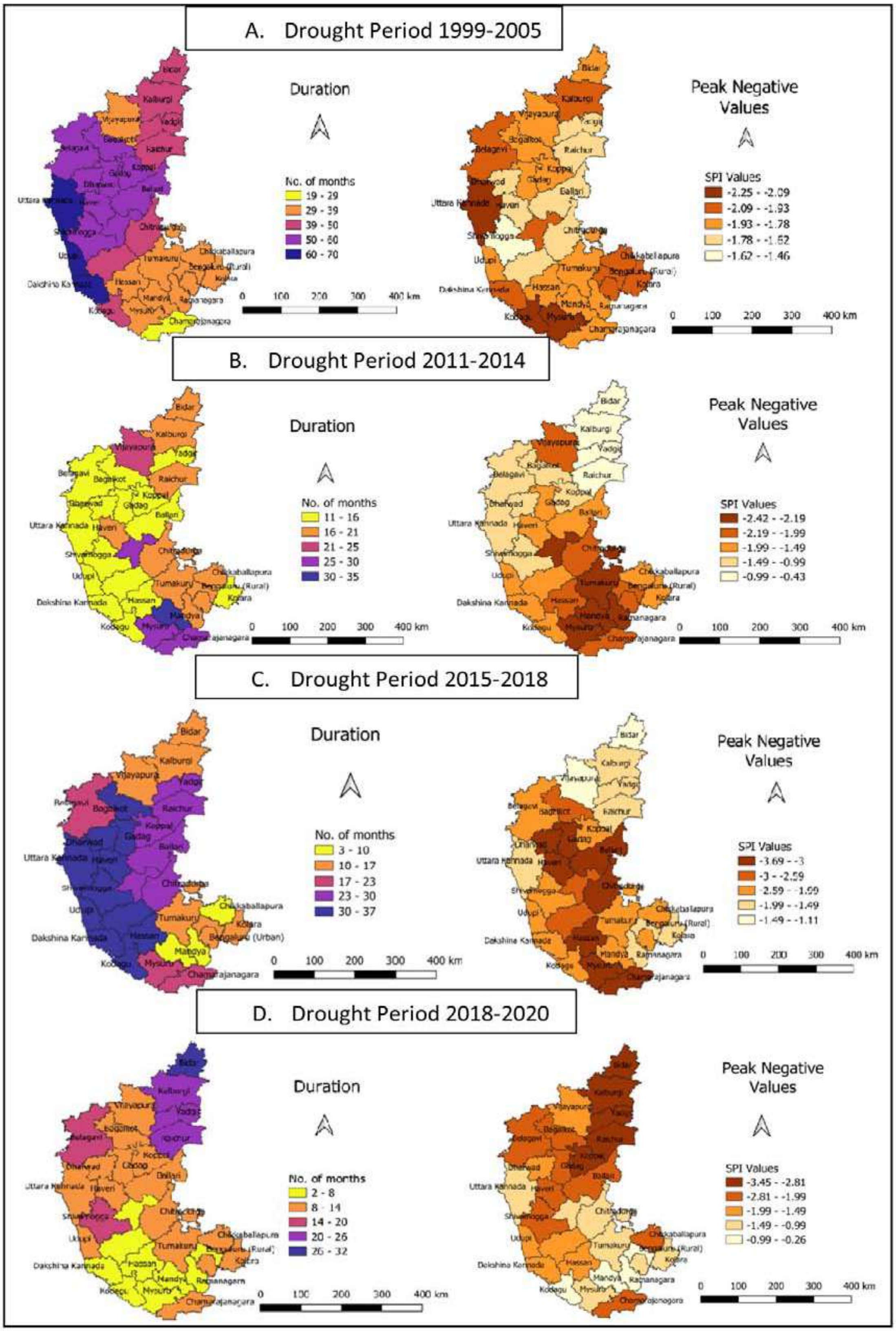


Fig. 3. Four significant drought periods – their duration and peak negative values in Karnataka

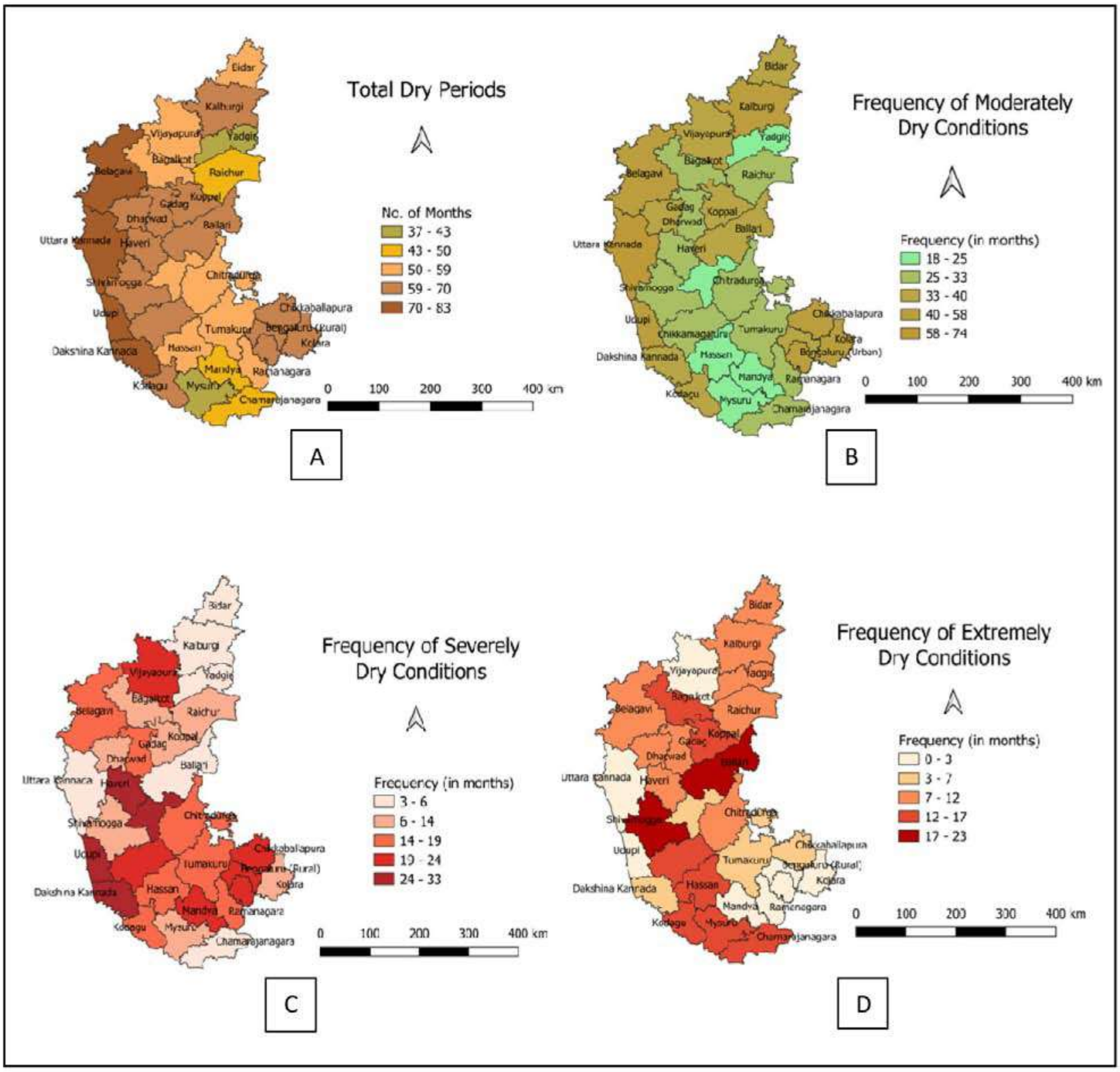


Fig. 4. Total number of dry periods and their category-wise frequencies in the period of 1990-2020 in Karnataka

1990 and 2020 in Karnataka, using Standardized Precipitation Index (SPI) measure for the 12-months timescale. The results showed that the drought intensity in the last decade is higher than that of the previous decades. The incidents of deficit rainfall could be observed for almost half of the duration of the study period. The drought periods are occurred more frequently in recent years with shorter dry spans but with greater intensities and generally followed with an increasedquantum of rainfall. The coastal and northern districts are more frequently affected by El Niño events when compared to the Southern districts of the State. The results from this study could be utilized tounderstand the trends and patterns of dry spells and wet spells.

The agricultural setbacks arising due to drought could be minimized by the adoption of change in cropping and irrigation techniques that focus on lesser water requirements. The policymakers could design crops missions/ projects to deal with frequent droughts. The results of this study could be taken in retrospect while designing crop insurance plans as well. Measures to counter the issues of surface water and groundwater deficiency; ponds, wells constructions, rainwater harvesting system, plantation, etc. could be planned by citizens and authorities. Further research could explore the causal relationship in depth between ENSO cycles and other climatic phenomenon and drought.

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PRICE-BEHAVIOUR AND FORECAST OF CHILLI PRICES IN ANDHRA PRADESH: A COMPARATIVE ANALYSIS USING ARIMA AND ANN MODELS

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ABSTRACT

The research was undertaken to study the price behaviour and forecast the prices of chilli in Andhra Pradesh using ARIMA and ANN along with comparing the forecast performance of these models using secondary data from June 2007 to July 2021. The results revealed that seasonal indices ofchilliarrivals were high in February to April and low in January and May (53.68), whereas, the prices were high in the month of November (104.46), January (102.78) and February (103.61) while low in April (92.93) and January (97.85).The price forecast for normal and special varieties of chilli was done using ARIMA and ANN models. ARIMA (3,1,2) and (1,1,1) had been identified as a best fit model for normal and special varieties respectively, ANN 6-24-1 (6 input nodes, 24 hidden nodes, and 1 output) and 8-20-1 (8 input nodes, 20 hidden nodes and 1 output node) outperformed all other neural networks for normal and special varieties, respectively. The study concluded that ANN model performed well and provided better estimates with more accuracy over ARIMA model due to their superior predictive ability in nonlinear and heterogonous data sets. The analysis concluded that the forecast price of normal varieties in the months of November 2021 and January 2022 may be Rs.6504 and Rs.7177, respectively and the forecast price of special varieties in the months of November 2021 and January 2022 might be Rs.13241 and Rs.11861, respectively.

Key Words: ANN, ARIMA, Chilli, Forecast, Non-linear and Price Behaviour

INTRODUCTION

Spices are traditional aromatic vegetables used for the seasoning of foods. Among these, chilli is one important spice used all over the world. Indian chillies have been dominating the international market. India is not only the biggest producer but also the largest consumer and exporter of different varieties of chilli in the world. Chilli contributes 42% of thetotal spice exports of the country. Indian chilli is exported to countries such as China, Vietnam, Thailand, Srilanka, Indonesia and Malaysia. Indian chilli is considered to be world famous for important commercial qualities of colour and pungency

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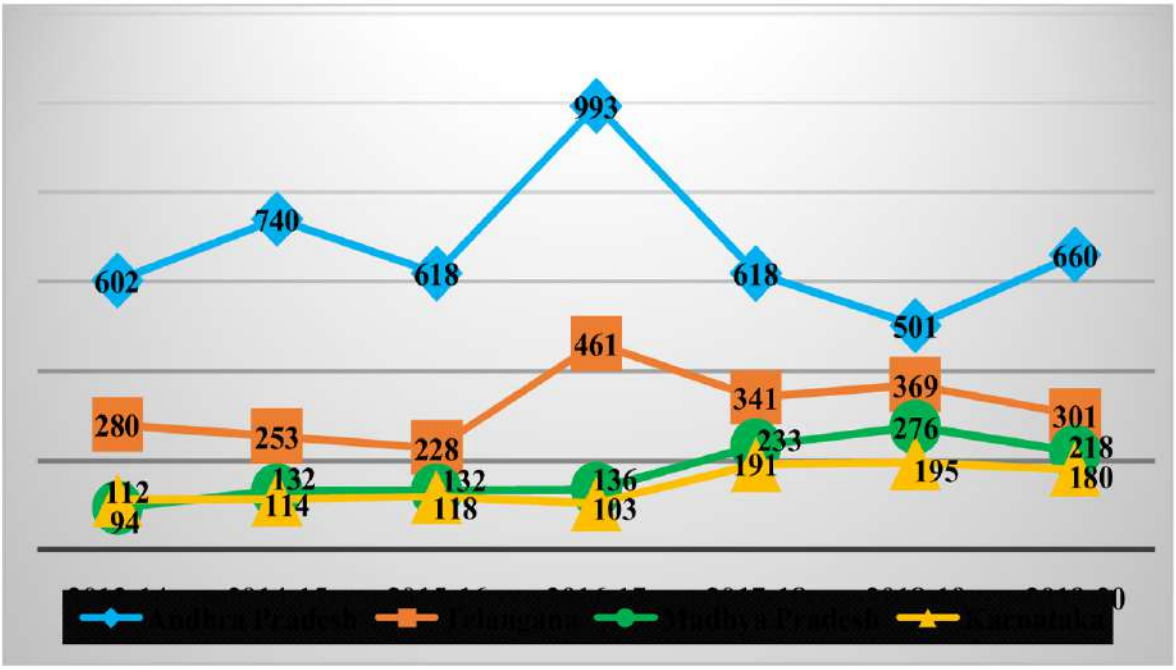

Fig. 1. Chilli production of major states; Source: Indiastat, 2020

levels. India is the largest producer with 1.70 million tonnes and contributes 43% of world chilliproduction followed by China, Ethiopia, Thailand, Pakistan and Bangladeshduring 2019-20.

In India, during 2020-21, Andhra Pradesh tops in dry chilli production with 6.52 lakh tonnes covered under 1.77lakh ha through 4588 kg ha^{-1} productivity followed by Telangana, Madhya Pradesh, Karnataka and West Bengal.Guntur chillimarket yard is the largest chilli market in Asia, which can influences the domestic and international prices of chillies. Guntur district in Andhra Pradesh produces 15% of all types ofchillies produced in India and the state of Andhra Pradesh as a whole contributes 38% of India's chilliproduction (APDES, 2020). There are more than 400 different varieties of chillies found all over the world. The major chilli growing districts in A.P are Guntur, Prakasam, Kurnool and Krishna.Teja, Byadgi, DD Best, 341, 273, 334, etc. are reported as premium varieties and preferred by exporters.

In any competitive economy, the pricing mechanism provides the signals to the producers in deciding what and how much has to be produced with the available resourcesfor maximizationofwelfare. Price forecasting is an integral part of commodity trading and price analysis and is used to provide aid to decision-making for planning for the future effectively and efficiently. Quantitative accuracy with small errors, along with turning point forecasting power, is important for evaluating forecasting models. Statistical forecasting models are used to develop an appropriate forecast methodology by using the past data to predict the future with the help of the trends and patterns for any parameter.The creation and enhancement of time series forecasting models have received a lot of attention during the last few decades. One of the most important and widely used is Auto-Regressive Integrated Moving Average (ARIMA) model.The popularity of this model is due to its statistical properties as well as the use of well-known Box-Jenkins's methodology in the model-building process. The major drawback of ARIMA is presumption of linearity, hence, no nonlinear patterns can be recognised by the model. Sometimes the time series often contain nonlinear components, under such conditions the ARIMA models are not adequate in modelling and forecasting. To overcome this difficulty, many parametric non-linear models are available to capture the nonlinear component (Rathod *et al.,* 2018). These parametric nonlinear models sometimes fails if the data generating process is highly heterogeneous, complex and nonlinear in nature. To model such data artificial intelligence techniques are the only way to model and forecast such phenomenon. The Artificial Neural Network (ANN) is the most widely used Artificial Intelligence (AI) techniques to model and forecast the time series data and has recently received a lot of interest as an alternative methodology for forecasting (Zhang *et al.*, 1998; Jha *et al.*, 2009). In view of the above, to study the price behaviour and forecast the prices of chilli in Andhra Pradesh, both the ARIMA and ANN models were employed with a due comparision of forecast performance of both to arrive at valid results.

MATERIAL AND METHODS

For the study, monthly secondary time series data about modal prices normal and special varieties of chilli were collected from the various Agricultural Market Committee (AMC) for the period from June2007 to July 2021. The analysis was carried out by using the Ratio to moving average method for seasonal index analysis and ARIMA and ANN techniques for forecasting theprices.

Seasonal Indices

The analysis of seasonal indices was carried out with the help of the data on month-wise prices of chilli from June 2007 to May 2021 for the agricultural year. Seasonal indices were calculated using the ratio to moving average method, Ratio to moving average method is one of the simplest of the commonly used analysis for measuring seasonal variation. The secondary data of prices was arranged by years and months. The quarterly total was calculated and then two months total was calculated. Average centred value was estimated and its percentage with initial market arrivals and prices was known. The percentage values are then arranged month-wiseand its average was estimated month-wise. The average of total average gives the seasonal index of the months under analysis.

Forecasting Models

The monthly prices for normal and special varieties of chillifromJune2007toJune 2020 were used for model building and data pertaining to the period July 2020 to July 2021 was used to model validation for forecasting. The analysis has been carried out in R software using tseries, forecast,fnonlinear, outliers and nnetar packages to model and forecasting chilli prices for a period of 6 months from August 2021 to January 2022. The data was tested for normality using box-whisker plot and outliers were tested using Grubbs test.

$$G = \frac{max_{i=1,...,N}\left|Y_i - \bar{Y}\right|}{s}$$

in which, $\bar{Y}$ = sample mean and s = standard deviation

ARIMA (Auto-Regressive Integrated Moving Average) models are a powerful class of models which can be applied to many real time series. These models consist of three parts: (1) an autoregressive part; (2) a moving average part; and (3) a part involving the first derivative of the time series. ARIMA has got advantage over linear regression as the latter only works with observed variables while ARIMA incorporates unobserved variables in the moving average part; thus, ARIMA is more flexible (Padhan, 2012). The full specification of an ARIMA model comprises the orders of each component, (p, d, q), where p is the number of preceding values in the autoregressive component, d is the number of differencing, and q is the number of preceding values in the moving average component. The model is carried out by using Box-Jenkins Methodology which in turn consists of four stages, *viz*., (i) identification; (ii) Estimation; (iii) Diagnostic checking; and (iv) Forecasting (Box and Jenkins, 1976).

i) Identification: The first step of Box-Jenkins forecasting model is to identify the appropriate order of ARIMA (p, d, q) model. Identification of ARIMA model implies selection of AR (p), MA (q) and I (d). The order of 'd' was estimated through I (0) or I (1) process of unit root stationarity test. In this study, the data series was checked for stationarity by using Augmented Dicky-Fuller (ADF) unit-root test by running regression of the following specification as specified by Dickey and Fuller (1979):

$$\Delta Y_t = \alpha + \beta_i T + \delta_i Y_{t-i} + b_i \sum_{i-1}^{p} \Delta Y_{t-i} + e_t$$

in which,

Y_t = Response variable at time 't'

ΔY_{t-i} = $Y_{t-1} - Y_{t-2}$ (t-i – lagged series and Δ – differenced series);

T = Time trend;

α = Drift (constant) parameter;

and b_i = Coefficients;

ε_t = Pure white noise error-term; and

P = Number of lags necessary to obtain white noise or to remove serial correlation in residuals.

In this model, the ADF tests the null hypothesis that the price series (Y_{it}) has a unit root and price series are not stationary (i.e. non-stationary). This is done by calculating t-statistics for δ_i = 0. If the coefficient δ is not statistically different from zero,it implies that the series have a unit root, and, therefore, the series is non-stationary. If the value of the ADF statistics is less than the critical value at the conventional significance level (usually at 5 per cent significance) then the series (Y_{it}) is said to be stationary and *vice-versa.* The critical values for this test are negative and larger than the standard t values and are given in Engle and Yoo (1987). If the computed value (at level) is smaller than the critical ' ' statistics, the null hypothesis of non-stationary series is not rejected. If Y_{it} is found non-stationary at levels i.e. I (0) then it should be determined whether it is stationary at 'n' differences i.e. Y= (Y_{it}-Y_{it-1}) ~ I (n) by repeating the above given specification.

Another way for testing stationarity is to compute the auto-correlation functions (ACF) of difference series [Y_i] up to 24 lags. If the

ACF for first and higher differences (after 2-3 lags) drop abruptly to zero, then it indicates the series is stationary. This method was also attempted to determine stationarity in this study.

Selection of order 'p' and 'q': The model specification and selection of order 'p' and 'q' involves plotting autocorrelation (ACF) and partial autocorrelation functions (PACF) or correlogram of variables at different lag lengths. The autocorrelation functions specify the order of moving averages process, q and partial autocorrelations select autoregressive of order p. The ACF shows autocorrelation coefficients at different lag length with 95 per cent confidence interval whether they are statistically different from zero or not. Order of AR *i.e*. p and MA *i.e.,* q is obtained by the examination of PACF and ACF plots respectively. Number of lagged values outside the limit is the order of the model. The significance level of individual coefficients was measured by Box-Pierce Q statistics and for all the coefficients jointly together by Ljung-Box statistics. The Box-Pierce Q statistics test is given by:

$$Q_m = n(n+2)\sum_{k=1}^{n}(n-k)^{-1}r_k^2 \approx \chi_{m-r}^2$$

in which, r_k^2 = Sample autocorrelation at lag K;

n = Number of observations

m = Number of time lags included in the test

When the p-value associated with the Q is large the individual coefficient is considered adequate for 5 per cent level of significance else the whole process has to start again (Rahman *et al.,* 2013). On the contrary, Ljung – Box Statistics tests whether a group of autocorrelations of a time series are less than zero. The test statistic as used by Hamjah (2014) was specified in the study as:

$$\mathbf{Q = T(T{+}2)}\textstyle\sum_{k=1}^{s}\frac{r_k^2}{T-K}$$

In which:

T = Number of observations;

S = Length of coefficients to test autocorrelation; and

= Auto correlation coefficient (for lag k)

If the sample value of 5ØDÜ exceeds the critical value of a 5Øß^2 distribution with s degrees of freedom, then at least one value of r is statistically different from zero at the specified significance level.

ii) Estimation of parameters

Once the order of p, d and q are identified, next step is to specify appropriate regression model and estimate it. To obtain least square estimates of the parameters such that the error sum of squares is minimum. The appropriateness of p, d and q values of the model and their statistical significance was judged by t-distribution.

Several models were compared, and the best fitting model were selected on the basis of the minimum values of Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and the maximum value of Coefficient of Determination (R^2) and Adjusted R-square as suggested by Padhan (2012) and Mahapatra and Dash (2019).

iii) Diagnostic checking

The ARIMA (p,d,q) model is assumed to be efficient when the residuals estimated from it are of white noise. The residuals of the fitted models were used for diagnostic checking. The estimated model must be checked to verify if it adequately represents the series.

In addition, an overall check of the model adequacy was made using the modified Box-Pierce Q statistics. The test statistics is given by:

$$Q_m = n(n+2)\sum_{k=1}^{n}(n-k)^{-1}r_k^2 \approx \chi^2_{m-r}$$

in which, r_k^2 = Residuals autocorrelation at lag K;

n = Number of residuals

m = Number of time lags included in the test

When the p-value associated with the Q is large the model is considered adequate, else the whole estimation process has to start again in order to get the most adequate model. Here all the tests were performed at the 5 percent level of significance.

iv) **Forecasting:** Once the three previous steps of ARIMA model are over, then we were able to obtain the forecasted values by estimating appropriate model. ARIMA models were used to forecast the corresponding variable. The accuracy of the forecasts for ex-post was tested for the minimum values of Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and maximum value of coefficient of determination (R2) and adjusted R-square.

Artificial Neural Network (ANN) Model

Neural Networks are data-driven, self-adaptive, nonparametric statistical method which mimic the human brain. The main advantage of a neural network is its ability to model complex non-linear relationship without a prior assumption of the nature of the relationship. The ANN model performs a nonlinear functional mapping from the past observations $(y_{t-1}, y_{t-2}, .., y_{t-p})$ to the future value y_t, *i.e.,*

$$y_t = f(y_{t-1}, y_{t-2}, \dots, y_{t-p}, w) + \varepsilon_t$$

in which,w is a vector of all parameters and f is a function determined by the network structure and connection weights. The important task of the ANN modelling for a time series is to choose an appropriate number of hidden nodes (k) as well as the dimensions of the input vector p (the lagged observations). The ANN model was employed as outlined in Areef and Radha (2020).

A multilayer feed forward neural network was fitted to the data with the help of nnetar package, which is extensively used for fitting univariate time series. According to the AIC, the optimal number of lags used as inputs. As a result, the fitted model is called an NNAR (p,P,k) model, which is analogous to an ARIMA (p,0,0) (P,0,0) model but with non-linear functions.

Forecast evaluation methods

The forecasting ability of different models is assessed with respect to common performance measures, *viz.,* the Root Mean Squared Error (RMSE), the Mean Absolute Error (MAE), Mean

$$RMSE = \sqrt{\frac{\sum_{t=1}^{T}(\hat{y}_t - y_t)^2}{T}}$$

- Mean absolute percentage error (MAPE)

$$MAPE = \left[\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100\right]/n$$

- Mean absolute error (MAE)

$$MAE = \frac{1}{T}\sum |y_t - \hat{y}_t|$$

- Deviations of predicted prices from the actual prices

$$forecast\ error(\%) = \frac{y_t - \hat{y}_t}{y_t} \times 100$$

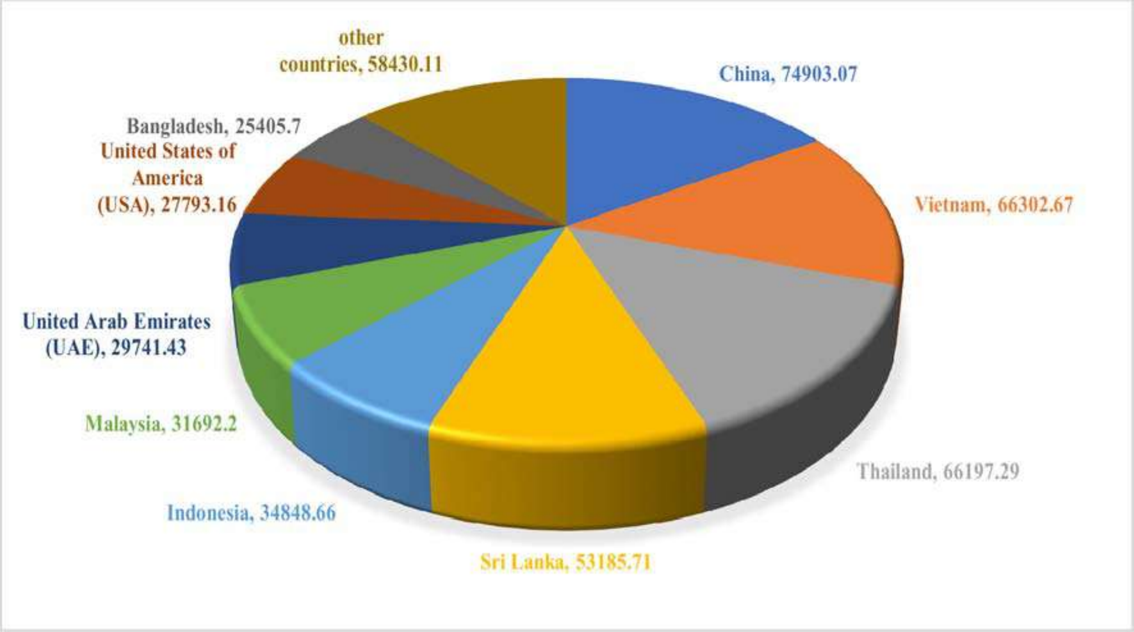

Fig. 2. Major importing countries of Indian chilli (2018-19); Source: Indiastat, 2020

Average Percentage Error (MAPE) and percentage of forecast error.

Where, y_t= actual prices, $\hat{y}_t$= predicted prices, ε_t=forecast error, T= sample size

The comparison of both the ANN and ARIMA was done using the above parameters for the future forecasting of chilli normal and special variety prices of Andhra Pradesh. Similar comparision was made by Vijay and Mishra for Bajracrop(2018).

RESULTS AND DISCUSSION

Table 1 shows that the share contributed by chilli to total spices export has increased from 19% to 42% between 1993 and 2020 and similarly the share of imports to total spices import has decreased from 1.27% to 0.51% from 2000 to 2018. It is learnt that major share is contributed by chilli crop which in turn contributes to nations GDP. In New Delhi city, a London based chilli importing company has opened its branch with highly equipped laboratory to purchase chilli at 40% to 50% high prices from farmers when met with their quality standards (Andhra Prabha, 2021). The major countries that import Indian chilli are presented in Fig. 2. The Figure 2 depicts that China is the major importer of Indian chilli followed by other counties like Vietnam, Thailand, Srilanka, Indonesia and Malaysia (87 percent of total India's chilli exports.)

Before the bifurcation, combined Andhra Pradesh produced a major share of chilli in India. The major districts contributing to chilli production are Guntur, Prakasam, Khammam and Warangal. The details of area and production of chilli of Andhra Pradesh and Telangana states is depicted in Table 2. It is observed that in Andhra Pradesh from 2010-11 to 2020-21, the area has declined from 1.95 to 1.80 lakhs, while the production has increased from 6.38 to 8.36 lakh tonnes which was due to an increase in the yield from 3271 to 4644 kg ha^{-1}. Even though the area after bifurcation declined, the production has increased implying that the productivity has increased with the available area.

Table1. Export and Import share of chilli to the total spices export and import for triennium years of India

Years	Exports (000' tonnes)			Years	Imports (000' tonnes)		
	Chilli	Spices	Percent share		Chilli	Spices	Percent share
1993-96	35.68	180.25	19.79	**2000-03**	1.07	83.95	1.27
1996-99	53.52	236.08	22.67	**2003-06**	1.11	100.62	1.11
1999-02	65.35	238.24	27.43	**2006-09**	0.96	100.11	0.96
2002-05	101.89	289.00	35.26	**2009-12**	1.16	101.54	1.15
2005-08	156.89	389.45	40.28	**2012-15**	0.69	133.48	0.52
2008-11	210.67	499.67	42.16	**2015-18**	0.98	191.78	0.51
2011-14	284.83	715.93	39.78	-	-	-	-
2014-17	364.92	906.16	40.27	-	-	-	-
2017-20	465.47	1103.77	42.17	-	-	-	-

Source: www.indiastat.com

Table 2. Comparision of area and production of chilli before and after bifurcation of Andhra Pradesh

Particulars	Before Bifurcation 2010-11		After Bifurcation 2015-16		2020-21	
	AP	India	AP	India	AP	India
Area (lakh ha)	1.95	7.92	1.56	8.10	1.80	7.43
Production (lakh tonnes)	6.38	12.23	6.18	15.19	8.36	19.14
Yield	3271	1544	3961	1875	4644	2576

Source: Agricultural statistics at a glance, Andhra Pradesh, 2019-20

Table 3. Inter-District Comparison of area and production of Chilli in Andhra Pradesh (2019-20)

Major Districts	Area (ha)	Rank in Area	Production (in tonnes)	Rank in Production
Guntur	77000	1	456000	1
Prakasam	35000	2	132000	2
Kurnool	15000	3	70000	4
Krishna	14000	4	101000	3
Ananthapur	4000	5	13000	5
East Godavari	2000	6	10000	6
Total		147000		782000
Other districts		6000		21000
Andhra Pradesh		**153000**		**805000**
Share (%)		**96.07**		**97.14**

Source: Agricultural statistics at a glance, Andhra Pradesh, 2019-20.

Table 4. Seasonal indices of chilli of Andhra Pradesh from 2007-2021

Month	Arrivals	Prices
June	79.99	99.07
July	116.17	98.75
August	109.2	101.22
September	97.99	98.28
October	89.18	101.37
November	101.88	104.46
December	83.30	99.64
January	79.86	97.85
February	115.09	102.78
March	140.59	103.61
April	133.07	92.93
May	53.68	100.02

Inter-district comparision of Andhra Pradesh for chilli (2019-20) is shown in Table 3.The Guntur district ranks first in both area and production followed by Prakasam district. Out of the 13 districts of Andhra Pradesh, six districts *viz.,* Guntur, Prakasam, Kurnool, Krishna, Anantapur and East Godavari covers 96 percent of acreage and contributes to 97 percent of production.

Seasonal indices of chilli

The reduced prices were experienced by the farmers' forfive years during the last decade and it is being observed that from 2018-19, the market prices are remunerative to farmers. Seasonal indices were computed by adopting ratio to moving average method for agricultural year from June 2007 to May 2021 for prices and arrivals of normal and special varieties of chilli in Andhra Pradesh (Table 4). The results revealed that the arrivals were high in February to April and low in January and May (53.68), whereas, the prices were high in the month of November (104.46), January (102.78) and February (103.61) while low in April (92.93) and January (97.85). Similar results were observed in Lakshmi *et al.* (2018) where the arrivals were observed to be high from February to April. The results in the Table reveal that the indices of arrivals were recorded maximum during March (140.59) and minimum in May (53.68). The arrivals started picking up from July onwards to the end of November. The seasonal index for prices being lowest in April (92.93) and the highest in November and March (104.46 and 103.61), respectively. The price index ranged from 92.93 to 104.46 for the chilli prices from June 2007 to May 2021. In April, higher arrivals resulted in a little decrease in prices of chilli and in May lower arrivals resulted in higher prices in Andhra Pradesh. The research findings stated by Srikala *et al.* (2016) were in line with this study as it reported prices that ranged from 92.52 to 102.94.

Fitting of ARIMA model

The time series plot of chilli prices for both normal and special varieties of Andhra Pradesh for the agricultural year from June 2007 to July 2021 has been taken for the analysis and ARIMA model has been built. The original time series was found to be non-stationary that it has no constant mean and variance, so first differencing was done to make the stationary series time series and confirmed by running a Augmented Dickey Fuller unit root test (ADF) for both varieties. The box whisker plot which shows the normality of data is presented in Fig. 3. The Grubbs test for outliers showed that the G value for normal and special varieties is 2.30 and 2.42, respectively, and p-value is 1 for normal varieties

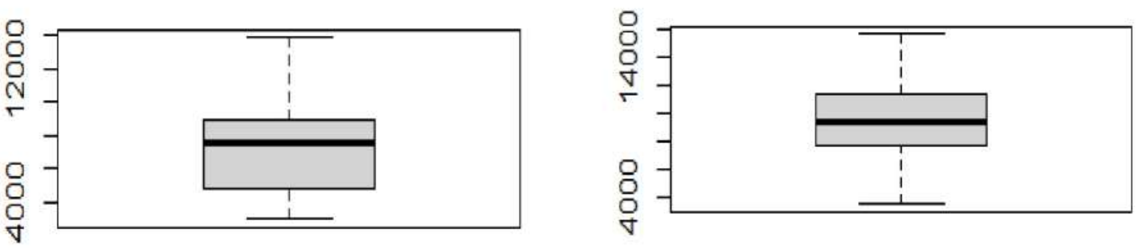

Fig. 3. Box-whisker plot for chilli normal and special varieties in Andhra Pradesh

Table 5. Augmented dickey fuller test for prices of chillinormal and special varieties in Andhra Pradesh

Lags	Chilli Normal Varieties				Chilli Special Varieties			
	at levels		at first difference		at levels		at first difference	
	ADF	p-value	ADF	p-value	ADF	p-value	ADF	p-value
0	-2.85	0.056	-16.04	0.01	-2.45	0.145	-10.32	0.01
1	-2.34	0.196	-8.96	0.01	-2.72	0.079	-8.84	0.01
2	-2.58	0.100	-7.82	0.01	-2.29	0.216	-6.10	0.01
3	-2.54	0.117	-5.87	0.01	-2.65	0.090	-5.46	0.01
4	-2.86	0.055	-5.67	0.01	-2.60	0.098	-4.80	0.01

and 0.89 for special varieties. As the p value is not less than 0.05, we fail to reject null hypothesis which implies that data is devoid of outliers. The detailed results of the ADF test are presented in Table 5. Several models were run and identified based on theautocorrelation and Partial Autocorrelation Function (ACF and PACF) plots of chilli normal and special varieties.

Table 6 depicts that the best fit ARIMA model for chilli prices of normal varieties, *i.e.,* ARIMA (3,1,2) has been identified based on the highest R^2 (0.843) and least AIC (2859.76), RMSE (1098.699), MAPE (11.60) values,whereas, for chilli prices of special varieties, ARIMA (1,1,1) has been identified based on the highest R^2 (0.816) and least AIC (2075.66), RMSE (1074.901), MAPE (8.63) valuesfor the price forecast in Andhra Pradesh. The values of all tentatively identified models are shown in Table 6 and parameters of the selected model were estimated for normal and special chilli varieties (Table 7).

Auto correlation check for residuals of the fitted model can be found out by Ljung-box test. The p-value of the Ljung-box test for chilli prices of normal varieties was0.616 (>0.05), and for chilli special varieties was0.2271 (>0.05) indicating the independence or non-autocorrelation of residuals. Most of the residuals of ACF in Figures 4 and 5 fall within the significance limit, indicating the adequacy of fitted model (*i.e.,* residuals are white noise).The forecast prices of the fitted model from August 2021 to January 2022 are given in the Table 11 and depicted in Figures 6 and 7.

Table 6. Tentative models for prices of normal and special chilli varieties in Andhra Pradesh

ARIMA model	Model selection criterion (Normal varieties)				Model selection criterion (Special varieties)			
	R^2	AIC	RMSE	MAPE	R^2	AIC	RMSE	MAPE
ARIMA(0,1,1)	0.79	2081.92	1123.075	9.04	0.832	2862.95	1137.336	11.69
ARIMA(1,1,0)	0.79	2082.17	1124.212	9.08	0.834	2861.43	1132.193	11.69
ARIMA(1,1,1)	**0.816**	**2075.66**	**1074.901**	**8.63**	0.838	2859.98	1115.721	11.62
ARIMA(2,1,1)	0.808	2082.62	1098.645	8.96	0.838	2860.37	1115.021	11.65
ARIMA(2,1,2)	0.807	2081.00	1100.397	8.98	0.838	2862.37	1115.052	11.65
ARIMA(3,1,0)	0.808	2082.62	1098.644	8.96	0.838	2862.63	1122.717	11.66
ARIMA(3,1,1)	0.800	2082.62	1098.617	8.96	0.839	2862.35	1114.975	11.65
ARIMA(3,1,2)	0.808	2080.62	1098.644	8.96	**0.843**	**2859.76**	**1098.699**	**11.60**

Table 7. ARIMA best fit model parameter of normal and special chilli varieties prices

Model		Coefficients		Estimate	SE
Normal chilli varieties	ARIMA(3, 1, 2)	AR	Lag 1	0.0482	0.2121
			Lag 2	0.7503	0.1323
			Lag 3	-0.0252	0.1047
		MA	Lag 1	-0.2464	0.2001
			Lag 2	-0.6899	0.1964
Special chilli varieties	ARIMA(1, 1, 1)	AR	Lag 1	-0.8281	0.0528
		MA	Lag 1	1.0000	0.0249

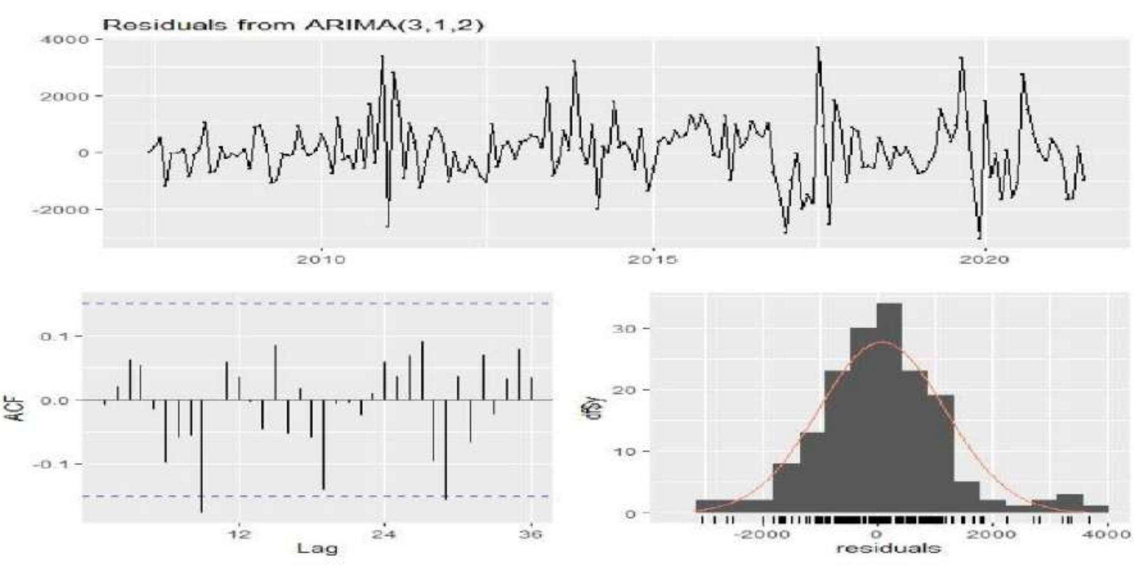

Fig. 4. ARIMA fitted (3,1,2) model residuals plot of chilli prices of normal varieties

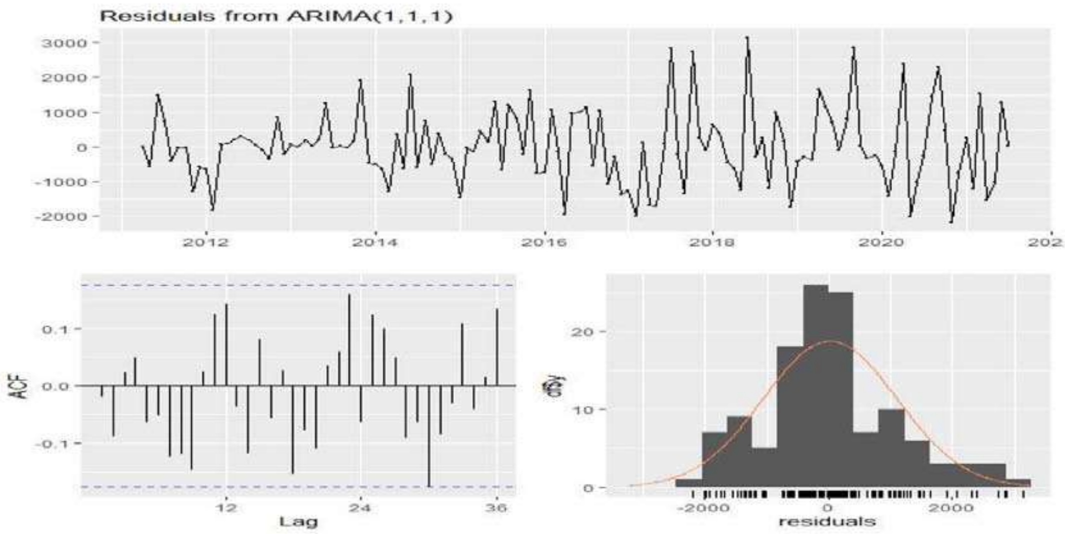

Fig. 5. ARIMA fitted (1,1,1) model residuals plot of chilli prices of special varieties

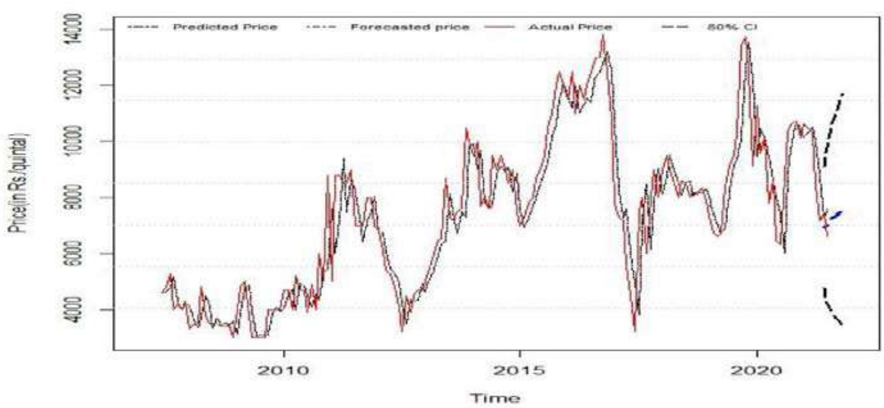

Fig. 6. Actual v/s fitted plot of ARIMA model normal varieties chilli prices of Andhra Pradesh

Fig. 7. Actual v/s fitted plot of ARIMA model normal varieties chilli prices of Andhra Pradesh

Fitting of ANN model

The neural network model 6-24-1 for normal varieties of chilli, many combinations of time lag, hidden nodes have been tried and based on the lowest training error, as a result, 6 lags were identified as optimal for network input nodes, 24 hidden nodes and one output layer. Various network topologies were trained by increasing the number of hidden nodes from 1 to 35 with sigmoidal activation function with one output layer with a linear identity function was selected. Among several, the 10 best performing models are listed based on the lowest of MAPE, RMSE, MAE, and MASE values (Table 8). A neural network 6-24-1(6 input nodes, 24 hidden nodes, and 1 output) outperformed all other neural networks with lower MAPE (2.089), RMSE (201.817), MAE (133.158), and MASE (0.057) values. The model has been cross validated 100 folds to minimize the error. The p-value of the Ljung-box test for chillinormal variety prices was 0.2935(>0.05), indicating the independence of residuals and Figure 8illustrated the residuals values of the selected model.

From the Table 9 prior selection of the neural network model for chilli special varieties, various topologies were trained by increasing the number of hidden nodes from 1 to 35 with

Table 8. Performance of different numbers of neural network models for normal varieties of chilli prices

Network structure	RMSE	MAE	MAPE	MASE
6-21-1	223.214	152.454	2.406	0.065
6-22-1	218.902	148.021	2.322	0.063
6-23-1	214.099	143.411	2.257	0.061
6-24-1	**201.817**	**133.158**	**2.089**	**0.057**
6-25-1	206.970	135.858	2.144	0.058
6-26-1	200.959	131.221	2.091	0.056
6-27-1	188.609	120.075	1.933	0.051
6-28-1	188.989	120.905	1.916	0.052

Table 9. Performance of different numbers of neural network models for special varieties of chilli prices

Network structure	RMSE	MAE	MAPE	MASE
8-15-1	112.981	37.412	0.463	0.015
8-16-1	110.607	35.083	0.439	0.014
8-17-1	100.016	29.986	0.375	0.012
8-18-1	100.587	28.971	0.369	0.012
8-19-1	97.005	25.734	0.329	0.010
8-20-1	**90.277**	**23.470**	**0.305**	**0.009**
8-21-1	92.608	23.873	0.309	0.010
8-22-1	90.229	23.550	0.305	0.009

sigmoidal activation function with one output layer with linear identity function was selected. Among the several, the 10 best performing models the neural network model8-20-1 (8 input nodes, 20 hidden nodes, and 1 output)was selected which outperformed all other neural networks with lower MAPE (0.305), RMSE (90.277), MAE (23.470), and MASE (0.009) values and are listed in Table 9. The p-value of the Ljung-box test for chilli special varieties prices was 0.7536 (>0.05), indicating the independence of residuals and Figure9 illustrated the residuals values of the selected model.

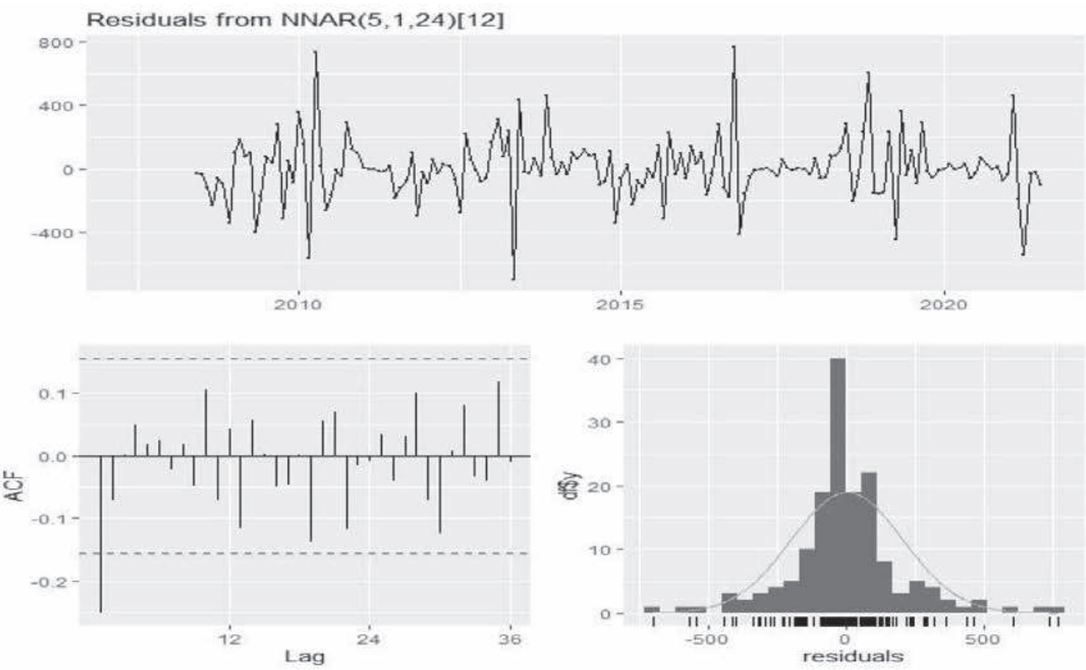

Fig. 8. ANN residuals plot of normal varieties of chilli

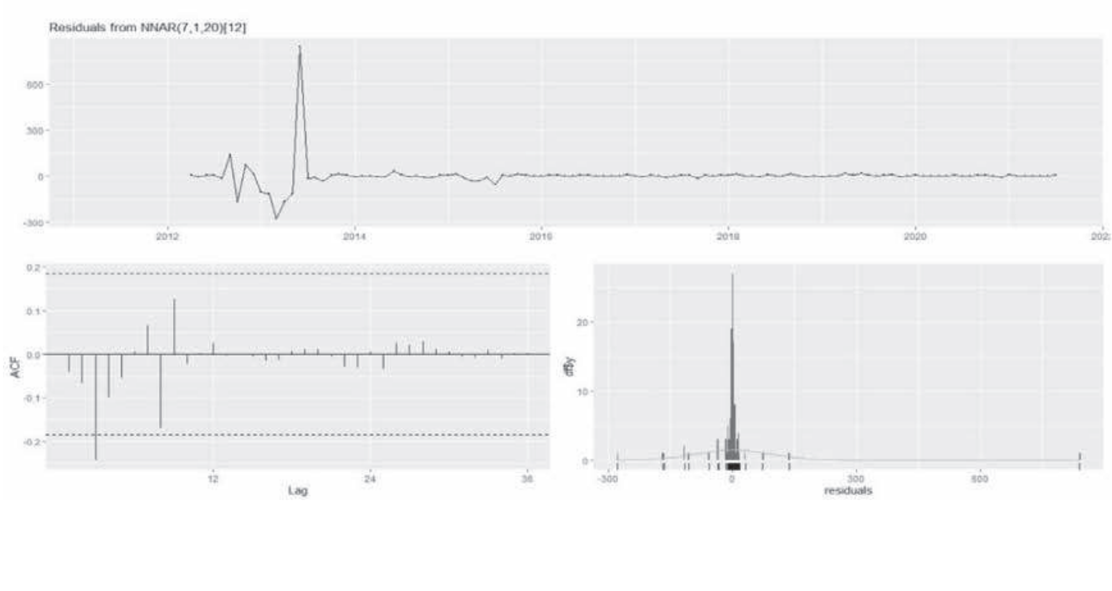

Fig. 9. ANN residuals plot of special varieties of chilli

Comparision of forecast performance of ARIMA and ANN

ARIMA models are not always adequate for the time series that contains non-linear structures. In this context, a nonlinear artificial intelligence technique like neural networks can be an effective way to improve forecasting performance. Based on the results obtained in this work one can infer that the application of artificial intelligence techniques like artificial neural networks technique in forecasting of time series can increase the forecasting accuracy. Comparative performance of fitted models was examined through computing mean absolute percentage error (MAPE), root mean square error (RMSE), mean absolute error (MAE) and mean absolute scaled error (MASE) criterion for both training and testing data set considered, one can infer that machine intelligence techniques, *viz.,* artificial neural network outperformed over ARIMA model for both the normal and special varieties of chilli. Similar results were observed in Jha and Sinha (2013) where they found that the ANN model is better at forecasting than ARIMA for agricultural prices. The results presented in Table 10 shows that the ANN model for normal and special varieties reported with lesser values of MAPE (2.089, 0.3052), RMSE (201.817, 90.277), MAE (133.158, 23.470) and MASE (0.057, 0.0094) compared with the ARIMA model. Both ex-ante and ex-post forecasts obtained through best fitted ANN and ARIMA models were compared to actual prices of chilli for Andhra Pradesh (Table 11) andillustrationis given in Figures 10 & 11, which revealed that there were narrow variations in between the actual and predicted values of ANN compared to ARIMA. For normal chilli varieties the forecastprices have been decreasing steadily upto December 2021 with price Rs.6051 per quintal and then in January 2022 the price has increased to Rs.7177 per quintal as per ANN forecast while as per ARIMA best fit model the chilli prices have been showing an increasing trend from August 2021 (Rs.6943 per quintal) to January 2022 (Rs.7523 per quintal).For special chilli varieties the forecast prices have been decreasing upto January 2022 with price Rs.11862 per quintal as per ANN forecast, while as per ARIMA best fit model the chilli prices have been showing consistent trend from August 2021 (Rs.11694 per quintal) to January 2022 (Rs.11691 per quintal). The artificial neural network model performed well over ARIMA model due to their superior predictive ability in nonlinear and heterogonous data set.The percent deviation for both chilli varieties using ARIMA was less than 30%, whereas, for ANN it was less than 1%, showing the superiority of ANN.

Due to increase shipping costs, export demand in spot markets for Indian chilli has been decreasing in July and also export contracts are pending for delivery to importing countries. Due to this, there will be a chance of low demand to chilli market and hence prices for chillies may see a downfall in the coming months and the same is predicted in the price forecast. The analysis concluded that the forecast prices of normal varieties of chilli may be Rs.6951, Rs.6712, Rs.6504, Rs.6051 and Rs.7177 in the months of September, October, November, December 2021 and January 2022. Similarly in case of special varieties, the forecast prices might be Rs.14015, Rs.13730, Rs.13241, Rs.12875 and Rs.11862 for the same months.

Table 10. Forecast Performance of ARIMA and ANN models

Criterion	Chilli normal varieties		Chilli special varieties	
	ARIMA	ANN	ARIMA	ANN
RMSE	1098.699	201.817	1074.901	90.277
MAE	802.899	133.158	797.67	23.470
MAPE	11.602	2.089	8.63	0.3052
MASE	0.342	0.057	0.949	0.0094

Table 11. Comparision of predicted values with actual prices ofchillinormal varieties prices in Andhra Pradesh

Period	Actual Prices (Rs./q)		Predicted Prices (Rs./q)				Percent deviation			
			Normal		Special		Normal		Special	
	Normal	Special	ARIMA	ANN	ARIMA	ANN	ARIMA	ANN	ARIMA	ANN
Jul-20	6333	11200	7392.6	6363.8	11453.37	11199.65	-16.73	-0.49	-2.26	0.00
Aug-20	8756	12383	6026.44	8685.78	10931.27	12385.23	31.17	0.80	11.72	-0.02
Sep-20	10371	15156	8902.97	10345.5	12858.55	15153.2	14.16	0.25	15.16	0.02
Oct-20	10674	15629	10024.9	10674	15149.87	15626.21	6.08	0.00	3.07	0.02
Nov-20	10710	13521	10666.5	10702.3	15705.79	13521.65	0.41	0.07	-16.16	0.00
Dec-20	10130	12331	10439.8	10204.9	13087.46	12340.45	-3.06	-0.74	-6.13	-0.08
Jan-21	10630	12831	10167.8	10664.9	12563.97	12823.74	4.35	-0.33	2.08	0.06
Feb-21	10500	11475	10317.9	10040.9	12678.26	11474.92	1.73	4.37	-10.49	0.00
Mar-21	10308	12940	10519.7	10499.7	11405.22	12939.58	-2.05	-1.86	11.86	0.00
Apr-21	8464	11701	10115.2	9010.59	13249.78	11703.44	-19.51	-6.46	-13.24	-0.02
May-21	7157	10150	8787.13	7185.16	11180.18	10149.24	-22.78	-0.39	-10.15	0.01
Jun-21	7438	11681	7255.98	7459.99	10412.86	11682.75	2.45	-0.30	10.86	-0.01
Jul-21	6614	11689	7597.19	6711.82	11676.65	11685.4	-14.87	-1.48	0.11	0.03
Aug-21	-	-	6934.69	6363.95	11694.68	12929.91	-	-	-	-
Sep-21	-	-	7003.13	6951.01	11689.98	14015.01	-	-	-	-
Oct-21	-	-	7267.82	6712.92	11693.87	13730.05	-	-	-	-
Nov-21	-	-	7323.86	6504.50	11690.65	13241.36	-	-	-	-
Dec-21	-	-	7523.43	6051.23	11693.32	12875.55	-	-	-	-
Jan-22	-	-	7568.43	7177.74	11691.11	11861.75	-	-	-	-

CONCLUSION

Seasonal indices of chilli from 2007 June to 2021 revealed that arrivals were high in February to April and low in January and May (53.68), whereas, the prices were high in the month of November (104.46), January (102.78) and February (103.61) while low in April (92.93) and January (97.85). The forecast for chilli normal and special varieties prices was done using ARIMA and ANN models. ARIMA (3,1,2) and (1,1,1) had been identified as best fit model with MAPE values of 11.60 and 8.63 for normal and special varieties, respectively, ANN neural network 6-24-1 (6 input nodes, 24 hidden nodes, and 1 output)and 8-20-1 (8 input nodes, 20 hidden nodes and 1 output node) outperformed all other neural networks with MAPE values of 2.089 and 0.3052 for normal and special varieties, respectively. The forecasting error for both chilli varieties using ARIMA was less than 30% and for ANN the forecast error was less than 1%.The results concluded that artificial neural network model performed well over ARIMA model due to their superior predictive ability in nonlinear and heterogonous data set. As the export contracts are pending for delivery to importing countries there will be a chance of low demand to chilli market and hence, prices for chillies may see a downfall in the coming months which is predicted in the price forecast. The analysis concluded that the forecast price of normal varieties in the months of November 2021 and January 2022 may be Rs. 6504 and Rs. 7177, respectively. Similarly for special varieties, the forecast price in the months of November 2021 and January 2022 may be Rs.13241 and Rs.11861, respectively.

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FACTORS AFFECTING CONSUMER AWARENESS TOWARDS CAMEL MILK USING BINARY LOGISTIC REGRESSION

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ABSTRACT

Camel milk is rich in nutrition, vitamins and is widely accepted for treating diseases. The study aimed to measure the awareness level among the consumers towards Camel milk. The study used an exploratory research approach and judgmental sampling technique for data collection in Gandhinagar, Gujarat. Binary logistic regression was performed to determine the socio-demographic factors that affect consumer awareness towards Camel milk.The study reported that awareness of Camel milk among the respondents was around seventy percent from the sampled responses. The study was performed during the period December 2020 and includes 388 respondents (Mean=30 and SD= 1.85). The findings recorded that only education is essential in raising consumer awareness of camel milk. The marketer should focus on creating awareness about the benefits of using camel milk and its palatability.

Keywords: Awareness Level, Binary Logistic Regression, Camel Milk, Consumer Awareness

INTRODUCTION

The livestock sector has emerged as a critical component in making agriculture more accessible and sustainable in India. According to data from the National Sample Survey Office 70th round of the survey, nearly a fifth (23%) of agricultural households with small plots (less than 0.01 hectares) relied on cattle as their primary source of income. Farms with cattle are better able to withstand adversity due to severe weather conditions. In 1998, India was named the world's leading milk producer and had the world's largest bovine population (National Dairy Development Board (NDDB), 2017). As per the Department of Animal Husbandry and Dairying (DAHD), milk output in India increased by 6.65 percent from 1950-1951 to 2017-18, from 17 million tonnes to 176.4 million tonnes, compared to 165.4 million tonnes in 2016-17. Food and Agriculture Organisation (FAO) reported a 1.4 percent increase in global milk production of 852 million tonnes in 2019from 2018 (Food and Agriculture Organisation of the United Nations, 2020). The country's per capita availability of milk increased from 130 g per day in 1950-51 to 374 g per day in 2017-18, compared to the world's estimated average consumption of 294

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g per day in 2017 (NDDB, 2017). It reflects a consistent increase in the availability of milk and milk products for the country's rising population.

Dairy farming has become a significant secondary source of income for millions of rural people. Subsequently, it has taken the lead in providing job and revenue generation options, particularly for marginal and female farmers. Around 48 percent of total milk output in India is eaten at the producer level or sold to non-producers in rural areas. The remaining 52 percent of the milk is marketable that is available for selling to urban consumers. The organised sector is expected to handle approximately 40% of the milk sold from the marketable surplus, *i.e.*, 20% each by cooperative and private dairies. In comparison, the unorganised sector will handle the remaining 60% (DAHD, 2020).

Camel milk has the same composition as Cow milk, although it is somewhat saltier (Yagil, 2013). Camel milk contains three times as much vitamin C as cow milk, making it an essential source of this vitamin for those living in dry and semi-arid climates where fruits and vegetables are scarce (Abbas *et al.*, 2013). Camel milk also contains various B-Vitamins and unsaturated fatty acids(Sharma and Singh, 2014; Gebremichael *etal.*, 2019). Only fresh or fermented camel milk should be consumed. Although protein and lactose levels are equivalent, milk from Bactrian camels has more fat than milk from dromedaries (Muli *et al.*, 2008).

As per the change in Indian policy, the sale of cattle, buffaloes, bulls, cows, bullocks, calves, and camels for slaughter in open markets was banned by the Ministry of Environment and Forests under the Prevention Cruelty to Animals Act, enacted in May 2017. Farmers cannot sell their ageing and even out-of-milk domesticated animals for slaughter. The animal market could not be set up within 25 km of the state border and 50 km of an international border. Due to the Act's implementation, animal trading is immobile only, and farmers have lost Rs. 20,000 to Rs 30,000 per animal. Earlier male camels could be sold at an average price of Rs 25,000, but after the law, it is a ban from the sale, and now they are getting hardly Rs. 2,000 for male Camel (Scroll, 2020). In recent times of COVID-19, farmers are getting low prices for their milk due to the destruction of demand in the hotel industry, which consumes 25 percent of the total marketable surplus. The farmers were forced for their milk at low prices. Camel milk disters sa;e pf market is highly affected by this COVID-19, and AMUL's Camel milk market decreased due to the low transport facility in lockdown.

In contrast, "COVID-19 has helped the rise in order and inquiries for Camel milk products," said the co-founder of Aadvik Foods, an Indian start-up founded in 2016. The rise in order and inquiries of Camel Milk is due to the following reasons- Many past studies state the benefits of Camel milk. Presently people are getting awareness about the importance of consuming Camel Milk. Due to the Pandemic caused by Coronavirus, to maintain the immunity against Corona virus, people are more focused on getting immunity boosters, high minerals, and immunoglobins, served by Camel Milk (Akweya *et al.*, 2012; Yagil, 2013).

Camel milk products are in high demand in developed countries due to their high nutritional value and extended storage period (Cardoso *et al*., 2010; Eyassu, 2007). The camel products like pasteurised milk, fragmented milk, ice creams, puddings, cheese, butter, beauty products, cleaning soap bars, and many more are available in the market in limited quantities (Eisa and Mustafa, 2011). Therefore, there is a massive demand for the product, but the marketing problem must be addressed to realise the full potential of camel milk (Abbas *et al*., 2013). Many farmers or villagers sell camel milk as an income generation activity (Nori *et al*., 2018). In small quantities, the loose raw milkis sold to the consumers through informal marketing channels (Matofari *et al*., 2007). Marketing effectively reaches the customer and satisfies their latent need (Netemeyer *et al*., 2004). AMUL has started marketing Camel's milk in 3 cities as a pilot testing, but the question is: Is AMUL able to change the taboo of camel milk in Indian society or not? This study aimed to determine the consumer's awareness of Camel's milk in Gandhinagar.

MATERIALS AND METHODS

Design and Participants

This research used an exploratory research approach to determine the factors affecting consumer awareness towards camel milk. As the research was a quantitative study, so, therefore,the researchers have collected data usinga structured questionnaire.Five hundred respondents were selected through a judgemental sampling technique for the study, but 388 qualified for final analysis. It includes 329 males and 59 females between the age group of 21 to 65 years (Mean=30 and SD= 1.85) with average graduate-level education.The subsequent intention of the study is to impart knowledge regarding the benefits of Camel milk.

Procedure and Measures

The research aims at socio-demographic factors that affect consumer awareness towards camel milk. The AMUL has only launched camel milk in three Gujarat cities: Ahmedabad, Gandhinagar, and Kutch.The study was conducted in the capital of Gujarat, *i.e*., Gandhinagar, and collected 388 responses from nearby shopping malls and AMUL outlets from November 2019 to February 2020. The researcher has asked the individuals for their voluntary participation and assured total confidentiality, and that information would be strictly used for research purposes only. The questionnaire was categorised into two sections. The first section is about awareness towards Camel milk and the second section consists of demographic details.

Data Analysis

The data of the study were analysed using SPSS software. Binary logistic regression was performed to determine the socio-demographic factors that affect consumer awareness towards camel milk. As the awareness output of the response was collected on a dichotomous scale, binary logistic regression is the best-suited test to measure the dependent variable. The authors have measured the internal reliability of the questionnaire using Cronbach's alpha, which is 0.754. It indicated that the reliability of the questionnaire is acceptable when the value is more than 0.70; therefore, a questionnaire has a relatively high internal reliability.The instrument's validity was checked,and the statements were prepared after discussions with

Table1.Demographic profile of Participants(n= 388)

Particulars	Frequency	Percentage	
1. Gender	Male	329	84.2
	Female	59	15.8
2. Age (in years)	Young Age (below 25)	133	34.3
	Middle age (25 to 40)	103	26.5
	Old age (Above 40)	152	39.2
3. Education Qualification	Upto 12th	153	39.4
	Graduation	155	39.9
	Post-graduation and above	80	20.6
4. Annual Family Income (in Rs.)	Upto 2 Lakhs	78	20.1
	2 Lakhs – 5 Lakhs	153	39.4
	5 – 10 Lakhs	113	29.1
	Above 10 Lakhs	44	11.3
5. Awareness towards Camel Milk	Unaware	123	31.71
	Aware	265	68.29

Source: Author's Compilation

shopkeepers and experts' suggestions. Questionnaire items were measured on a scale of 1 to 7 with anchors "Strongly Disagree" to "Strongly Agree" for the construct measures.

RESULTS AND DISCUSSION

In the study, the SPSS output is simplified (Table 1) and depicts 84.2 percent of the respondents were male, and 15.8 percent were female; 34.3 percent were under the age of 25, *i.e.,* the young age group and 39.2 percent were over the age of 40 years, *i.e.,* old age group. Only 40 percent of students received diplomas, while only 20.6 percent completed post-graduate courses. The sample survey was bolstered by a diverse range of annual income levels. 39.4 percent of those involved are in the Rs 2 to 5 Lakhs category, 29.2 percent of those engaging are in the Rs 5 to 10 Lakhs bracket, and 20 percent of those responding are in the below Rs two Lakhs group. The demographic statistics may provide authors with a clear understanding of the research objective and the importance of the subject via the age, gender, education qualifications, and participants incomes.

A binary logistic regression model

Four socio-demographic factors, namely age, gender, education, and income, are considered to study the factors that affect consumers' awareness of Camel milk. The following Binary logisticregression model is developed for the study:

Consumer's Awareness = $a + b_1.X_{1i} + b_2.X_{2i} + b_3.X_{3i} + b_4.X_{4i} + u_i$

Two types of categories in this model are considered to be dependent on consumer awareness. Consumer's awareness =1 for Aware, consumer's awareness =2 for Unaware. X_{2i} is the age in year and they are categorised into X_{2i}=1 for Young Age (below 25); X_{2i}= 2 for Middle age (25 to 40); X_{2i}= 3 for Old age (Above 40). X_{3i} is the education, where three categories of education are considered, and they are quantified as follows: X_{3i}=1 for upto 12th level education; X_{3i}=2 for Graduation level education; X_{3i}=3 for post-graduation and above education. X_{4i}= is the income in INR, and diversified into four groups, X_{4i} = 1for below 2 Lakhs; X_{4i}=2 for 2 to5 Lakhs; X_{4i}=3 for 5 to 10 Lakhs; X_{4i} =4 for Above 10 Lakhs. Furthermore, u_i is the disturbance term.

The objective of the study is to measure theconsumer's awareness of Gandhinagar city towards Camel Milk.The study used four hypotheses to identify the results of the goal:

Framed Hypotheses of the study

H_1: Awareness of Camel milk is significantly dependent on the age of the consumer.

H_2: Awareness of Camel milk is significantly dependent on the gender of the consumer.

H_3: Awareness of Camel milk is significantly dependent on the education of the consumer.

H_4: Awareness of Camel milk is significantly dependent on the Income of the Consumer.

Factors affecting the awareness of Camel Milk

A binary logistic model is used to study the factors that affect camel milk awareness levels among consumers.Logistic regression explains and predicts the probability of an event occurring (Subject to awareness towards Camel Milk = 1 as in Group 1, and Subject to unawareness towards Camel Milk = 0 as in Group 2). Four socio-demographic factors, namely age, gender, annual income, and education, are considered independent variables in the analysis. 'Aware; and 'unaware' are the binary inputs of the dependent variable. Groups were mutually exclusive and collectively exhaustive. One subject could belong only to one group.

The result of binary logistic regression is shown in the following Tables. The classification table is described as the overall accuracy of the model in Table 2 and Figure 1. The Classification Table indicated about the comparislon of observed and predicted groups to assess how many would be defined suitably.The overall accuracy of the model is observed at 66.5 percent. As the cut-off value was set at 0.5 and the percentage correct is more than that in this study consumer's awareness towards Camel milk is classified as Aware.

Table 2. Classification Table

Observed		Predicted		
		Awareness towards Camel Milk		**Percentage Correct**
		Aware	**Unaware**	
Awareness towards Camel Milk	**Aware**	227	38	85.7
	Unaware	92	31	25.2
Overall Percentage				**66.5**

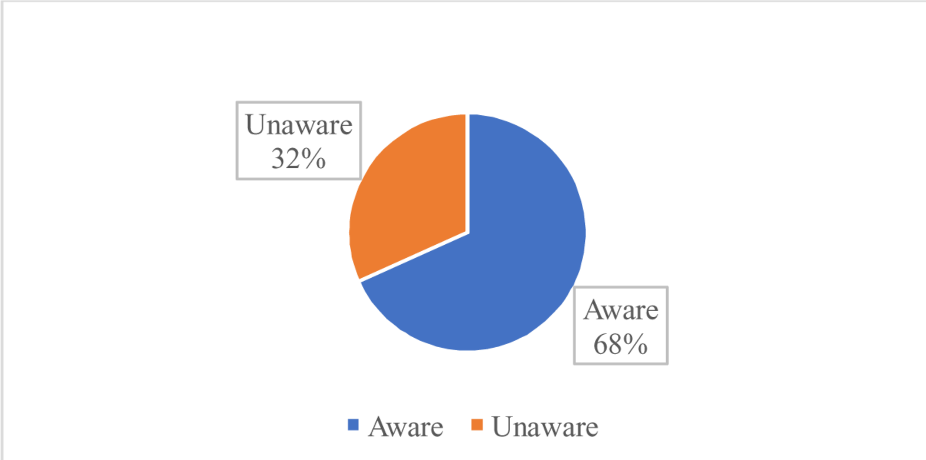

Fig. 1.Consumers awareness towards camel milk

Table 3. $\chi 2$ test

	$\chi 2$	df	Sig.
Step	42.678	8	.000
Block	42.678	8	.000
Model	42.678	8	.000

Table 4. R^2 Test

-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
442.008	0.104	0.146

The $\chi 2$ test shows a significant result (Table 3), indicating that this predictor model is significant for the present study. The logistic regression model was statistically significant, $\chi 2$ (8) = 42.678, p = .000.Cox & SnellR^2 and Nagelkerke R^2 are based on the model's log-likelihood and interpreted as indicating the amount of variation in the dependent variable explained by the model. The more value of the Nagelkerke R^2 shows the binary logistic regression model explains the more quantity of variation.The predictors in the model were indicated by Cox & Snell R^2 and Nagelkerke R^2 and explained .10 and .146 of the variation, respectively (Table 4). The Nagelkerke R^2value is 14.6% of the variation in survival can be explained by the model suggesting that predictions are fairly reliable.

As shown in Table 5, out of four variables, two variables, education and income, have a positive and significant impact on the consumer's awareness of Camel milk. Age and gender have a positive but insignificant effect on the consumer's awareness of Camel milk.

H_1: Awareness of Camel milk is significantly dependent on the age of the consumer

From Table 5, it is evident that hypothesis H_1 is not rejected as the significance value

Table 5. Likelihood Ratio Test

Factors	B	S.E.	Wald	df	Sig.	Exp(B)
Age			3.545	2	**.170**	
Age(1)	.157	.278	.319	1	.572	1.170
Age(2)	-.427	.315	1.839	1	.175	.653
Gender(1)	.671	.388	2.985	1	**.084**	1.955
Education			11.270	2	**.004**	
Education(1)	1.357	.432	9.861	1	.002	3.884
Education(2)	.673	.404	2.779	1	.046	1.960
Annual Income			8.252	3	**.041**	
Annual income(1)	-.244	.510	.229	1	.632	.784
Annual income(2)	-.518	.452	1.317	1	.251	.596
Annual income(3)	-1.085	.465	5.453	1	.020	.338
Constant	-1.631	.474	11.858	1	**.001**	.196

Variable(s) entered: Age, Gender, Education, Annual Income

$p>0.05$. Therefore, it means that awareness of Camel milk does not significantly depend on the consumer's age. Hence, it is concluded that the alternate hypothesis is failed to reject.

H_2: Awareness of Camel milk is significantly dependent on the gender of the consumer

Table 5 depicts that hypothesis H_2 is not rejected as the significance value is $p>0.05$. Hence, it means that awareness of Camel milk is not significantly dependent on the gender of the consumers of Gandhinagar. Thus, it is concluded that the alternate hypothesis is failed to reject.

H_3: Awareness of Camel milk is significantly dependent on the education of the consumer

From Table 5, however, hypothesis H_3 is rejected as the significance value is $p<0.05$. So, it can be understood that the awareness of Camel milk significantly depends on the consumer's education. Hence, it is concluded that the alternate hypothesis is rejected.

H_4: Awareness of Camel milk is significantly dependent on the Income of the Consumer

From Table 5, similarly, hypothesis H_4 is not rejected as the significance value $p>0.05$. Thus, it could be interpreted as the awareness about camel milk is not there among the respondents of all the income groups.Therefore, it means that awareness of Camel milk is not significantly dependent on the income of the consumer.

Hence, the study can be summarised as follows:

Logistic regression was performed to ascertain the effects of age, gender, education, and income on participants' likelihood ofawareness towards Camel milk. The logistic regression model was statistically significant, ÷2(8) = 42.678, p = 0.000. The model explained

10.4% (Nagelkerke R^2) of the consumer awareness variance and correctly classified 66.5 percent of cases. Only education was associated with an increased likelihood of exhibiting consumers' awareness towards Camel milk. Higher education (Graduation) is 3.884 times more likely to exhibit awareness of Camel milk than less educated (Below graduation) consumers. The results confirmed that the more educated person is likely to exhibit more awareness of Camel milk than the less educated person.

Sangkumchaliang & Huang's (2012) findings suggested that consumer awareness is the main barrier in increasing the market shares of food products. In Spain, Briz & Ward (2009) has measured the customers' awareness level using a multinomial logistic regression model. Education plays a vital role in determining Organic food awareness levels (Demirtas, Parlakay, & Tapki, 2015). In determining the consumers' buying decisions, demographic factors have played a significant part.The study found that education is the only explanatory variable that is analysed through a binary logistic regression model. Sharma and Singh (2014) found that demographic factor is essential in understanding the consumption and demand of Camel milk. Therefore, the study states that if potential customers are aware of the importance of Camel milk, then it may increase the market for the milk and its consumption.

CONCLUSION

The study aimed to measure the awareness level among the consumers towardscamel Milk. Camel milk products are in high demand in developed countries due to their high nutritional value and extended storage period. However, the awareness level and usage of camel milkare low.The study's findings showed that only education is essential in raising consumer awareness of camel milk. According to the study, understanding the benefits of using camel milk and advertising and social awareness programs will aid in shifting consumers from other cattle. The age, gender and annual income are not significantly dependent for raising the awareness of camel milk.

Most consumers are hesitant to consume camel milk due to its distinct taste and odour, but it can be altered by adding flavours. In 2017-18, Amul brand introduced flavoured camel milk, as well as chocolates. Furthermore, camel milk can be used to treat a variety of diseases and provide health benefits. A significant impact of awareness will lead to consumer purchasing and, ultimately, to securing health benefits. Finally, camel milk and its products are acceptable, and demand can be increased through increased awareness of therapeutic uses and regular consumption for health benefits.

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Research Note
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FARMERS PERCEPTION ON EFFECT OF COVID-19 ON AGRICULTURE AND ALLIED SECTORS IN GUNTUR DISTRICT OF ANDHRA PRADESH

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The recent outbreak of the novel SARS-CoV-2 virus, also known as corona virus 2019 (COVID-19), has evolved into one of the most serious pandemic situations in the past hundred years (Dhama *et al*., 2020; Sohrabi *et al*., 2020). Mishra *et al*. (2021) expressed that natural calamities like droughts are localized and used to affect only the associated sector or stakeholders, whereas the pandemic impacts the global supply chain bydisrupting food demand and supply). COVID-19 pandemic hadaffected all walks of life and extensively interrupted Indian agricultural system.In spite of all these measures taken by the Government, still there are negative implications of COVID-19 pandemic on the farm economy. In India, the immediate implications of this lockdown on the agricultural front were witnessed in the form of disruption of activities relating to harvesting and marketing of agricultural crops and commodities. Due to COVID-19 restricted movement of several essential services (particularly transportation) have been witnessed in the lockdown period and this has affected the operation of different agricultural activities. The nature of impact of lockdown has varied across regions and commodities. Keeping this in view, an attempt was made to analyse the perception of the farmers on the effect of Covid 19 on agriculture and allied sectors along with the constraints faced by them during and after lockdownperiod and their suggestions to overcome those constraints in future.

The investigation was carried out in Guntur district of Andhra Pradesh during the year 2020-21. *Ex-post* facto research design was used for this study. Six villages *viz*., Budampadu, Kesanapalli, Bellamkonda, Penumaka, A.Muppalla and Piduguralla were selected and from each village 10 farmers were randomly selected for the study purpose. Thus, the sample size was 60. Farmers of these villages were majorly cultivating cotton, rice, pulses and vegetbles. A structured interview schedule prepared by the Directorate of Extension was used for collecting information on the farmers perception on effect of Covid-19 on Agriculture and allied sectors. Information on constraints faced by the farmers and their suggestions were collected by posing open ended questions to the farmersand they were analyzed using mean and standard deviation for prioritization.

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Effect of Covid-19 on farming operations as perceived by the farmer

It could be inferred from the Table 1 that great majority of the farmers felt that due to Covid 19 changes were observed in loss of income (88.34%), changes in new social and behavioural norms (social distancing, wearing masks, maintaining hygiene) (81.67%), changes observed in availability of labour (supply/ demand) (80.00%), changes observed in marketing of produce and changes observed in expenditure on agriculture (66.67%), changes observed in demand and supply of inputs/ produce (63.33%), changes observed in price fall (58.33%), changes in psychological issues (risk taking ability/frustration/fear/depression/ confidence) and changes observed in cropping pattern/ crop area planning based on market demand (56.67%). Loss of income in farming sector was majorly attributed to the labour non-availability and increased cost of agricultural inputs due the pandemic restrictions. Dev (2020) observed that harvesting of the winter (November–March) crops such as wheat and pulses in the intensively cultivated north-western plains of Indiawas adversely affected due to reverse migration of labour causing labour scarcity. Barrett, (2020); Carberry and Padhee (2020) confirmed that the restrictions on movement interrupted the supply chains, obstructing the continuous flow of inputs for and outputs of agricultural activities. Harris *et al*. (2020) felt that as perishable commodities supply was affected more, assuring food and nutritional security of the vulnerable sections of the society become tough task.Availability of the labour is the major factor affected the cultivation as the majority of the farmers are involved in cultivation of rice, cotton and vegetables which are labour intensive crops. Reverse migration is another crucial aspect which adversely affected taking up agricultural operations in time and this ultimately might have led to unavoidable stress in farmers' minds and increased cost of cultivation.

Considerable percent of the farmers disagreed that changes observed in application of herbicides (58.33%), changes observed in application of fertilizers (55.00%), changes observed in rearing of milch animals (53.33%), changes observed in selection of crops (50.00%), changes observed in method of sowing and changes observed in rearing of sheep and goat (46.67%) and changes observed in adoption of technology (41.67%). From these results it is evident that even though changes were there in procurement of agricultural inputs, labour availability, cost of cultivation, price of inputs as well as produce and marketing of the produce, farmers have not changed their regular cultivation practices and adoption of technology. The probable reason for this behaviour of farmers is any deviation in adoption of technology and cultivation will drastically affect the yields and net profits. Hence farmers with all their efforts were able to apply fertilizers, pesticides and herbicides as such in pre Covid-19 situation. Even in regards to rearing of livestock not many changes were observed as they used to feed them with the locally available resources.

Constraints faced by farmers during Covid-19

From Table 2 it is evident that only eighty percent of the farmers faced the problem of labour unavailability this was mainly because of the lockdown restrctions on movement of vehicles, labour were unable to move from one

Table 1. Effect of Covid 19 on farming operations perceived by the farmer

n=60

	Impact items (please mention)	**Agree (3)**		**Undecided (2)**		**Disagree (1)**	
		Frequ-ency	**%**	**Frequ-ency**	**%**	**Frequ-ency**	**%**
1	Changes observed in loss of income	53	**88.34**	2	3.33	5	8.33
2	Changes observed in cultivated area	29	**48.33**	10	16.67	21	35.00
3	Changes observed in cropping pattern/ crop area planning based on market demand	34	**56.66**	13	21.67	13	21.67
4	Changes observed in selection of crops	23	38.33	7	11.67	30	**50.00**
5	Changes observed in method of sowing	24	40.00	8	13.33	28	**46.67**
6	Changes observed in leased amounts	28	46.67	13	21.67	19	31.67
7	Changes observed in availability of labour (supply/demand)	48	**80.00**	6	10.00	6	10.00
8	Changes observed in marketing of produce	40	**66.67**	13	21.67	7	11.66
9	Changes observed in rearing of milch animals	10	16.67	18	30.00	32	**53.33**
10	Changes observed in rearing of sheep and goat	12	20.00	20	33.33	28	**46.67**
11	Changes observed in rearing of poultry birds	15	25.00	25	**41.67**	20	33.33
12	Changes observed in rearing of fisheries	11	18.33	30	**50.00**	19	31.67
13	Changes observed in price fall	35	**58.33**	11	18.33	14	23.33
14	Changes observed in expenditure on agriculture	40	**66.67**	9	15.00	11	18.33
15	Changes observed in demand and supply of inputs/produce	38	**63.33**	12	20.00	10	16.67
16	Changes in psychological issues (risk taking ability/ frustration/fear/depression/confidence)	34	**56.67**	8	13.33	18	30.00
17	Changes in new social and behavioural norms (social distancing, wearing masks, maintaining hygiene)	49	**81.67**	4	6.66	7	11.67
18	Changes observed in consumer habits	25	41.67	24	40.00	11	18.33
19	Changes observed in agricultural operations	29	48.33	10	16.67	21	35.00
20	Changes observed in adoption of technology	19	31.67	16	26.66	25	**41.67**
21	Changes observed in application of fertilizers	16	26.67	11	18.33	33	**55.00**
22	Changes observed in application of plant protection chemicals (please mention)	11	18.33	19	31.67	30	**50.00**
23	Changes observed in application of herbicides	7	11.67	18	30.00	35	**58.33**

Table 2. Constraints faced by farmers during Covid-19 in agriculture and allied sectors

n=60

S. No.	Constraints	Frequency	%
1.	Labour unavailability	48	**80.00**
2.	Input availability	38	**63.33**
3.	Increased labour cost	35	**58.33**
4.	Increased cost of cultivation	33	**55.00**
5.	Unable to attend field operations timely	33	**55.00**
6.	Lack of storage godowns	30	**50.00**
7.	Markets were closed due to lock down	29	48.33
8.	Transportation problem	28	46.67
9.	Liquid cash not available	26	43.33
10.	Not getting minimum support price	25	46.67
11.	Poor medical facilities to livestock	15	25.00
12.	Food availability to labour	10	16.67

Table 3. Suggestions to overcome constraints expressed by the farmers

n=60

S. No.	Suggestions	Frequency	%
1.	Maintaining precautions	36	**60.00**
2.	Produce should be stored safely in godowns	33	**55.00**
3.	Establishing more rural godowns	30	**50.00**
4.	Adopting mechanization	29	**48.33**
5.	Saving money for future needs	23	38.33
6.	Local availability of inputs	20	33.33
7.	Adopting new technologies	17	28.33

place to another.Lockdown due to COVID-19 interrupted agricultural labour markets resulted in huge reverse migration. Imbert (2020) reported that 45% of the migrants returned home during lockdown. Another constraints experienced by the farmers during pandemic were input availability (63.33%), increased labour cost (58.33%), increased cost of cultivation and inability to attend field operations timely (55.00%), lack of storage godowns (50.00%), markets were closed due to lock down (48.33%) and transportation problem (46.67%). All the major constraints expressed by the farmers were highly interrelated. Labour unavailability due to lockdown restrictions had led to increased labour cost. Non-availability of inputs and increased cost of labour ultimately resulted in increased over all cost of cultivation. Non-availability of storage facilities at village level had compelled farmers for opting distress selling. Closing of markets had adversely affected the marketing of the produce. Forty three per cent of farmers felt non availability of liquid cash was the constraint faced by them. One-fourth of the farmers felt poor medical facilities to livestock was the problem during the pandemic. Almost seventeen per cent of the farmers felt non-availability of food to labour due to closure of hotels was the problem.

Suggestions to overcome Constraints expressed by the farmers

Farmers have suggested few measures to overcome the constraints faced by them during lockdown period. It could be noticed that regular agricultural activities need to be carried out by maintaining precautionary measures (60.00%), produce should be stored safely in godowns (55.00%), establishing more rural godowns (50.00%), adopting mechanization (48.33%), saving money for future needs (38.00%), making arrangement for availability of inputs locally (33.33%) and adopting new technologies (28.33%) were the suggestions given by the farmers (Table 3). Encouraging the farmers to store their produce in storage godowns by increasing number of storage godowns will definitely avoid distress selling by the farmers. Adopting mechanisation will definitely help the famers to cut down the cost of cultivation by minimising their dependence on labour. Adopting new technologies not only increases over all production, but, also certainly reduces the unnecessary expenses in cultivation.

It is concluded that construction of rural godowns, mechanisation in agriculture and adoption of modern technologies will address the changes and constraints experienced due to Covid-19 by the farmers.

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PERFORMANCE ANALYSIS OF PRADHAN MANTRI FASAL BIMA YOJANA IN INDIA

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The Indian agricultural sector is susceptible to risks. The sector mainly faces two types of risks; crop yield loss due to climatic aberrations and revenue loss due to the fluctuation in the market price of crops. Its contribution to the gross value added of the country gradually declined from 18.2% in 2014-15 to 17.8% in 2019-20 (Economic Survey of India, 2021). The reasons are low productivity, non-remunerative market prices and crop lossesConsequently, it exposed the farming community to the liquidation of assets, insolvency position, and poverty (Patnaik and Narayanan 2015). To address this issue,the Government of India (GOI) has inaugurated the Pradhan Mantri FasalBima Yojana (PMFBY) as a crop insurance scheme. It is been the fifth year since the scheme was introduced; many policy changes have been done relating to the rate of GOI's subsidycontribution to the states.Also, a new efforthas been made in terms of technology adoption under the scheme,such as usage of mobile-based technology to reduce the number of Crop Cutting Experiments (CCEs) and digitization of land records and to link them to farmers' accounts for faster assessment/ settlement of claims (Ravi Kumar and Nirmal, 2019). Against this backdrop, thestudy aims to analyze the physical and financial performance of PMFBY in India during *Kharif* 2016-17 to *Rabi* 2019-20 with the research hypothesis of there is a significant difference among the sum insured, farmers' premium, gross premium, claims reported and claims paid in the study area.

For the analysis of the physical and financial performance of PMFBY, required secondary data is collected from the 'Agricultural Statistics at a Glance' 2020, Directorate of Economics & Statistics, GoI website. The utilized data set covered cumulative data (from *Kharif* 2016-17 to *Rabi* 2019-20) of all the states and union territories, which are offering PMFBY to their farmers. To ease the analysis and help the policymakers to take the decision at the central level, the researcher classified the States and Union Territories (UTs) into seven regions namely, North part, Central part, East part, North-East part, West part, South part, and UTs of India. Analysis of Variance (ANOVA) was performed to compare the means of the sum insured, farmers' premium, gross premium, claims reported, and claims paid from *Kharif* 2016-17 to *Rabi* 2019-20 among the seven region in a consolidated manner. In addition, to determine the exact significance difference between the parameters, the Least Significant Difference (LSD) test was employed at 0.05 significance level as a post-hoc testwith the help of the Statistical Package for Social Sciences (SPSS) 25 version.

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Table 1. Cumulative Average Area, Sum Insured, Premium, Claims Receivedper farmer and Beneficiary Ratio from Kharif 2016-17 to Rabi 2019-20 under PMFBY in India

Region	States	Insured area per farmer (Hectare)	Sum insured per hectare (Rs.)	Premium per hectare (Rs.)	Claims received per farmer (Rs.)	Beneficiary ratio
North	Haryana	1.42	63578.40	3491.62	20412.70	25.69
	Himachal Pradesh	0.35	34949.70	1730.41	1859.25	23.10
	Rajasthan	1.11	27673.38	3618.72	11596.40	28.38
	Uttarakhand	0.56	68501.68	1532.75	2423.66	15.35
	Total	**1.13**	**34390.23**	**3568.05**	**12502.70**	**27.69**
Central	Chhattisgarh	1.06	33050.88	2940.27	13395.40	33.66
	Madhya Pradesh	1.69	31942.01	3576.68	21646.30	26.60
	Uttar Pradesh	0.84	44283.96	2616.78	7461.92	14.10
	Total	**1.27**	**35277.59**	**3251.63**	**16455.80**	**22.71**
East	Bihar	0.92	47190.57	5304.83	17248	8.66
	Jharkhand	0.43	55423.30	6465.91	3871.17	5.75
	Odisha	0.57	58911.54	7589.52	16439	26.11
	West Bengal	0.41	68435.50	3874.76	4965.63	18.40
	Total	**0.54**	**58414.51**	**5758.54**	**11199.70**	**17.69**
North-east	Assam	0.58	70650.59	2563.76	3969.39	0.89
	Manipur	1.40	35133.74	2250.51	2486.64	68.35
	Meghalaya	0.53	102257.94	3827.02	3775.88	16.67
	Sikkim	0.24	86516.85	1872.66	5190.31	12.77
	Tripura	0.20	63727.03	1887.41	1878.19	21.51
	Total	**0.58**	**69157.06**	**2543.33**	**2725.39**	**3.13**
West	Goa	0.54	106397.06	1470.59	6060.61	9.17
	Gujarat	1.32	48377.17	10828.7	20601.60	30.12
	Maharashtra	0.57	31903.32	5991.45	6113.74	47.96
	Total	**0.68**	**36515.02**	**7344.69**	**7492.43**	**45.40**
South	Andhra Pradesh	0.72	70927.91	6593.99	13983.30	32.41
	Karnataka	0.98	40165.42	7427.21	14191.20	45.75
	Kerala	0.83	92052.67	4240.97	16172.60	24.21
	Tamil Nadu	0.55	60744.04	11382.8	17743.50	56.83
	Telangana	0.92	72466.79	4156.47	10077.40	12.77
	Total	**0.77**	**56226.07**	**7770.49**	**15658.80**	**42.76**
Union Territories	A & N Islands	0.74	35236.40	2765.39	5084.75	19.58
	Jammu & Kashmir	0.83	71781.43	4509.06	9355.22	12.33
	Puducherry	0.81	57816.86	3877.1	16782	15.64
	Total	**0.83**	**70429.39**	**4447.52**	**10138**	**12.66**
Grand Total		**0.91**	**39657.03**	**4807.96**	**11747**	**31.17**

Source: Authors' calculation based on data collected from Agricultural Statistics at a Glance (DES, 2020).

Table 2. Cumulative Sum Insured, Farmers' Premium, Gross Premium, Claims Reported and Claims Paid from Kharif 2016-17 to Rabi 2019-20 under PMFBY in India

(Rs. in Lakhs)

Region	States	Sum Insured	Farmers' premium	Gross premium	Claims reported	Claims paid
North	Haryana	5266470	92523	289226	306502	305075
	Himachal Pradesh	102562	1491	5078	3638	3590
	Rajasthan	10483939	221749	1370936	1121116	1119090
	Uttarakhand	251482	3328	5627	2454	2454
	Total	**16104453**	**319091**	**1670867**	**1433710**	**1430209**
Central	Chhattisgarh	2997077	56924	266626	387737	386451
	Madhya Pradesh	15085205	269749	1689151	1634561	1609402
	Uttar Pradesh	8738447	161132	516363	249775	246928
	Total	**26820729**	**487805**	**2472140**	**2272073**	**2242781**
East	Bihar	2174935	38392	244491	74936	74936
	Jharkhand	1073535	9081	125243	60195	9938
	Odisha	3530989	69808	454894	459784	454928
	West Bengal	3724944	33262	210903	121753	121435
	Total	**10504403**	**150543**	**1035531**	**716668**	**661237**
North-east	Assam	486471	1324	17653	2177	415
	Manipur	10928	194	700	377	377
	Meghalaya	2672	80	100	31	31
	Sikkim	462	10	10	15	15
	Tripura	7732	171	229	243	243
	Total	**508265**	**1779**	**18692**	**2843**	**1081**
West	Goa	1447	17	20	14	14
	Gujarat	5381207	149944	1204527	543883	523214
	Maharashtra	9134626	220766	1715484	1478394	1476348
	Total	**14517280**	**370727**	**2920031**	**2022291**	**1999576**
South	Andhra Pradesh	2867377	45270	266573	258145	255221
	Karnataka	3299675	77829	610161	564706	545066
	Kerala	51312	1014	2364	5886	2635
	Tamil Nadu	3086517	54945	578383	939442	932762
	Telangana	2121853	38672	121703	72730	41044
	Total	**11426734**	**217730**	**1579184**	**1840909**	**1776728**
Union territories	A & N Islands	395	2	31	23	15
	Jammu & Kashmir	186575	2574	11720	3607	3607
	Puducherry	14301	22	959	1456	800
	Total	**201271**	**2598**	**12710**	**5086**	**4422**
Grand Total		**80083135**	**1550273**	**9709155**	**8293580**	**8116034**

Source: Authors' calculation based on data collected from Agricultural Statistics at a Glance (DES, 2020).

Table 3. Cumulative Financial Performance of PMFBY from *Kharif* 2016-17 to *Rabi* 2019-20 in India

Region	States	Gross premium to sum assured ratio	Claims paid to sum insured ratio	Claims paid to gross premium ratio	Claims paid to claims reported ratio
North	Haryana	5.49	5.79	105.48	99.53
	Himachal Pradesh	4.95	3.50	70.70	98.68
	Rajasthan	13.07	10.67	81.63	99.82
	Uttarakhand	2.24	0.98	43.61	100
	Total	**10.38**	**8.88**	**85.60**	**99.76**
Central	Chhattisgarh	8.90	12.89	144.94	99.67
	Madhya Pradesh	11.20	10.67	95.28	98.46
	Uttar Pradesh	5.91	2.83	47.82	98.86
	Total	**9.22**	**8.36**	**90.72**	**98.71**
East	Bihar	11.24	3.45	30.65	100
	Jharkhand	11.67	0.93	7.93	16.51
	Odisha	12.88	12.88	100.01	98.94
	West Bengal	5.66	3.26	57.58	99.74
	Total	**9.86**	**6.29**	**63.85**	**92.27**
North-East	Assam	3.63	0.09	2.35	19.06
	Manipur	6.41	3.45	53.86	100
	Meghalaya	3.74	1.16	31	100
	Sikkim	2.16	3.25	150	100
	Tripura	2.96	3.14	106.11	100
	Total	**3.68**	**0.21**	**5.78**	**38.02**
West	Goa	1.38	0.97	70	100
	Gujarat	22.38	9.72	43.44	96.20
	Maharashtra	18.78	16.16	86.06	99.86
	Total	**20.11**	**13.77**	**68.48**	**98.88**
South	Andhra Pradesh	9.30	8.90	95.74	98.87
	Karnataka	18.49	16.52	89.33	96.52
	Kerala	4.61	5.14	111.46	44.77
	Tamil Nadu	18.74	30.22	161.27	99.29
	Telangana	5.74	1.93	33.72	56.43
	Total	**13.82**	**15.55**	**112.51**	**96.51**
Union Territories	A & N Islands	7.85	3.80	48.39	65.22
	Jammu & Kashmir	6.28	1.93	30.78	100
	Puducherry	6.71	5.59	83.42	54.95
	Total	**6.31**	**2.20**	**34.79**	**86.94**
Grand Total		12.12	10.13	83.59	97.86

Source: Authors' calculation based on data collected from Agricultural Statistics at a Glance (DES, 2020).

Table 1 showed that Central states have the highest insured area per farmer (1.13 hectares),followed by Northern states, UTs, Southern states, Western states, North-eastern states, and Eastern states, respectively. It indicates that the small and marginal farmers were covered in the Eastern states extensively compared to the all-other region. In the sum insured per hectare,the UTs region has the highest, *i.e.,* Rs.70429 of the sum insured per hectare after thatNorth-eastern states, Eastern states, Southern states, Western states, Central states, and Northern states (Rs.34390). Southern states have paid the highest insurance premium per hectare (Rs.7770), whereas, North-eastern states have paid the lowest premium per hectare (*i.e.,* Rs.2543). Insurance companies have paid the highest claims per farmer to central states (Rs.16456). It is also observed that significantly feweramountof claims (Rs.2725) per farmer was paid in the North-eastern region compared to the all-other regions. In the ratio of the number of farmers who received indemnity to the total number of farmers insured in the particular region,Western states have the highest ratio (45.4%). North-eastern states have the very least ratio, *i.e.,* 3.13.

Table 2 reveals that Central states and Northern states have the highest sum assurance while North-east and UTs have less sum assured. In the Central states and the Western states, crop insurance companies have collected the highest amount of farmers' premium whereas, in the UTs and North-eastern states, it has collected the lowest amount of farmers' premium. In the case of gross premium, the highest amount has been collected from the Western states and the Central states, whereas, from North-eastern states and UTs a tiny amount of gross premium has been collected. The Central states and Western states have reported and received the highest amount of claims. In contrast,UTs and North-eastern states reported and received fewerinsurance claims than all other regions.

It is evident from Table 3 that Western states (20.11%) and Southern states (13.82%) have the highest ratio of gross premium to sum assured, but UTs and North-eastern states have the lowest ratio.Southern states and Western states have been paid the highest percent of claims against sum insured, whereas, UTs (2.2%) and North-eastern states (0.21%) have been paid very little. The Southern states have received the highest crop insurance claims (112.51%) and more than the total gross premium. It was followed by Central region states, which have received the second-highest claims (90.72%) against the total gross premium amount. It is also observed that UTs (34.79%) and North-eastern states (5.78%) have received less claims against the gross premium. In the Northern states (99.76%) and Western states (98.88%), the insurance companies have been settled the highest percent of the claims against the report of the claim. However, UTs (86.94%) and North-eastern states (38.02%) have been paid very less percent of claims against the claims reported during the period.

Table 4 illustrates the Analysis of Variance results. It is recorded that p-value 0.000088 is lesser than the 0.05 significance level. It resulted in the acceptance of the research hypothesis and rejection of the null hypothesis. Furthermore, it is inferred that there is a significant difference among the parameters in the seven regions. However, which parameters significantly differ from other parameters is not clear by the ANOVA

Table 4. Comparision of sum insured, farmers' premium, gross premium, claims reported, and claims paid under PMFBY

Groups	Sum of Squares	df	Mean Square	F value	Significance
Between Groups	617503813724924.100	4	154375953431231.030	8.691	0.000088*
Within Groups	532856397293912.000	30	17761879909797.066		
Total	1150360211018836.000	34			

Table 5. Multiple Comparisons of Sum Insured, Farmers' Premium, Gross Premium, Claims Reported, and Claims Paid under PMFBY

(Mean Difference in Lakh Rupees)

(I) Parameters	(J) Parameters	Mean Difference (I-J)	Std. Error	Significance
Sum insured	Farmers' premium	11218980.28571	2252736.74258	0.000*
	Gross premium	10053425.71429	2252736.74258	0.000*
	Claims reported	10255650.71429	2252736.74258	0.000*
	Claims paid	10281014.42857	2252736.74258	0.000*
Farmers' premium	Sum insured	-11218980.28571	2252736.74258	0.000*
	Gross premium	-1165554.57143	2252736.74258	NS
	Claims reported	-963329.57143	2252736.74258	NS
	Claims paid	-937965.85714	2252736.74258	NS
Gross premium	Sum insured	-10053425.71429	2252736.74258	0.000*
	Farmers' premium	1165554.57143	2252736.74258	NS
	Claims reported	202225.00000	2252736.74258	NS
	Claims paid	227588.71429	2252736.74258	NS
Claims reported	Sum insured	-10255650.71429	2252736.74258	0.000*
	Farmers' premium	963329.57143	2252736.74258	NS
	Gross premium	-202225.00000	2252736.74258	NS
	Claims paid	25363.71429	2252736.74258	NS
Claims paid	Sum insured	-10281014.42857	2252736.74258	0.000*
	Farmers' premium	937965.85714	2252736.74258	NS
	Gross premium	-227588.71429	2252736.74258	NS
	Claims reported	-25363.71429	2252736.74258	NS

***The mean difference is significant at the 0.05 level**

results. Therefore, the multiple LSD test is performed.

From Table 5, it is noticed that there is a significant difference between the sum insured and other parameters. It indicated that the sum insured amount is significantly more than farmers'premium, gross premium, claims reported, and claims paid. Despite having a mean difference between other parameters, it is statistically insignificant in the seven identified regions.

It is observed that there is a high level of acceptance of the scheme in the Central Statessince it has covered the highest number of farmers and crops area. Whereas, North-eastern states and UTs showed the low level of acceptance, this might be due to their small population and geographical area. The highest number of farmers were benefited in western states and in state-wise, Goa has the least number even though it belongs to the western states. It is found that there is a massive difference in beneficiary ratio among the regions; Western states such as have 45.4%, whereas, North-eastern states have only 3.13%, which could hamper the participation spirit of the farmers in the lowest ratio's region.While in the individual states, Manipur (North-eastern state) and Tamil Nadu (Southern states) have the highest ratio, while Jharkhand (Eastern state) and Assam have the least ratio. Through this, the results cannot be generalized region-wise. Hence, it is advised to the policymakers to consider the performance of the scheme region-wise as well as state-wise individually to make decisions effectively. North-eastern states have received the less claimsagainst gross premium (5.78%) and claims reported (38.02%) by the farmers; in this region, insurance companies were more benefited. Therefore, the region requires reform in the regulatory framework of the insurance companies. The ANOVA and LSD test results showed a significant difference between the sum insured and other parameters, which means the insurer collected very less gross premium and paid less claims compared to the sum insured in the overall seven regions. Therefore, it is advised to reform the loss assessment mechanisms so that the claims amount significantly matches with the sum assured amount.

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Research Note
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ASSESSMENT OF GENETIC VARIABILITY IN INDIAN BARNYARD MILLET GENETIC RESOURCES [*Echinochloa frumentacea* (L.)]

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Barnyard millet, also known as *Madira* or *Jhangora* or *sawan* is an ancient millet crop grown in warm and mild, moderate temperature regions of the world and widely cultivated in Asia, particularly India, China, Japan and Korea. It is the fourth most produced minor millet, providing food security to many poor people across the world. Globally, India is the biggest producer of barnyard millet, both in terms of area (0.146 m ha^{-1}) and production (0.147 MT) with average productivity of 1034 $kgha^{-1}$ during the last three years (IIMR, 2018). The major barnyard millet producing states in India are Uttarakhand, Madhya Pradesh, Karnataka, Uttar Pradesh and North east states of India. The two cultivated species of barnyard millet are Indian barnyard millet (*Echinochloa frumentacea*) and Japanese barnyard millet (*Echinochloa esculenta*).

Barnyard millet has high nutritional profile and high dietary fibre content.The importance of barnyard millet has increased due to its rich nutritious grains and presence of strong antioxidative compounds. The barnyard millet contains 10.5% protein, 3.6% fat, 68.8% carbohydrate, 51.5% to 59.5% starch and 398 $kcal100g^{-1}$energy. The total roughage content was high (12.6%) including soluble (4.2%) and insoluble (8.4%) fractions.

For any crop improvement work, information about the genetic variability available in the population is a prime requisite.Presence of high variability offers much scope for crop improvement.Knowledge on heritability and genetic advance of the character indicate the scope for the improvement of a character through selection. Heritability along with genetic advance are also helpful in predicting the grain yield under selection.

The study was carried out at Regional Agricultural Research Station (RARS), Nandyal, Andhra Pradesh (A.P).The selected 64 Indian barnyard millet genetic resources weregrown in a lattice square design, replicated twice during*Kharif*, 2020 in order to assess the genetic parameters *viz.,* variability, heritability and genetic advance as *per cent* of mean. The experiment was laid at an altitude of 211.3 m above mean sea level, latitude of 18.29°N and longitude of 78.29°E at RARS, Nandyal; The net plot size was 4.5 m^2 with a recommended spacing of 22.5 cm x 10 cm. Five plants were selected randomly for the collection of data in each replication for 18 metric traits *viz.,* days to 50% flowering, days to maturity recorded per plot basis,basal tillers, peduncle length (cm), flag leaf blade length (cm), flag leaf blade width(cm), plant height (cm),

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panicle length (cm), 1000 seed weight (g), panicle weight plant^{-1} (g), harvest Index (%),lower raceme length (cm), grain yield plant^{-1} (g), phosphorus (mg), calcium (mg), iron (mg), zinc (mg) and protein (%).

It is a known fact that greater variability would lead to better scope for selection and predicting accurately the yield of a crop. Therefore, for forming an appropriateselection programme, information about the extent of variability is very essential.The estimates of GCV were lower than PCV for all the traits under study (Table 1) indicated that the traits were impacted by the environmental conditions.The traits, number of basal tillers plant^{-1} (30.3 and 32.6) and lower raceme length (27.4-28.6) recorded higher GCV and PCV (>20) values respectively indicates that these traits contributed to the total variability. The results obtained byMahanthesha *et al*., (2017), Shingane *et al.*, (2017), Sharma *et al*. (2018) are similar for number of basal tillers per plant in barnyard millet, foxtail millet and finger millet. The traits like days to 50% flowering (14.3 and 15.5), peduncle length (13.5 and 14.9), flag leaf blade width (10.3 and 12.1), plant height (11.0 and 12.6), panicle length (15.7 and 16.9),1000 seed weight (18.4 and 19.8), panicle weight plant^{-1} (16.3 and 17.9), grain yield plant^{-1} (15.7 and 19.8), calcium (11.6 and 13.3), iron (11.1 and 13.0), zinc (13.6 and 15.3) and protein (14.6 and 16.2) were recorded with moderate PCV and GCV value. Similar findings were reported by Ganapathy *et al*.(2011) for grain yield plant^{-1} and plant height in foxtail millet. Brunda *et al*. (2014) for panicle length, panicle weight, test weight in foxtail millet. Low GCV and PCV values were recorded for the traits like days to maturity (6.9 and 9.3), harvest index (5.1 and 8.0) and phosphorus (2.4 and 4.4) indicating that the variability for these traits among the germplasm accessions was low. The similar findings were reported by Prabhu *et al*. (2020) and Ganapathy *et al*. (2011) are for trait days to maturity in barnyard millet and foxtail millet.Low GCV and moderate PCV values were alsoobserved for the trait flag leaf length (8.2 and 10.5) by Prabhu *et al.* (2020) in barnyard millet.

Heritability values in combination with genetic advance are more reliable and helpful genetic indicators for predicting genetic gain under selection than heritability estimates alone.High heritability (>60%) associated with high genetic advance as percent of mean (>20%) (Table 1& Fig. 2) was registered for the traits: number of basal tillers (86.4 and 58.1), days to 50% flowering (85 and 27.1), peduncle length (82.6 and 25.3), panicle length (86 and 30), 1000 seed weight (86.4 and 35.2), lower raceme length (92 and 54.1), grain yield plant^{-1} (63.1 and 25.7), zinc (78.5 and 24.8) and protein (75.5 and 25.2). Similar results were also reported by Anuradha *et al.,* (2017), Ganapathy*et al*. (2011),Karad*et al*. (2013), Brunda *et al.*(2014)for days to 50% flowering,Prabhu *et al.*(2020) and Brunda *et al.*(2014) for panicle length,number of tillers plant^{-1} and grain yield plant^{-1} in barnyard millet and foxtail millet, respectively.

For all of the traits studied, genetic parameter analysis revealed that GCV estimates were lower than the corresponding PCV values, indicating that the traits were impacted by the environment and thus providing ample scope for trait evolution through simple phenotypic selection. For the traits of basal tillers plant^{-1}, days to 50% flowering, peduncle length, panicle

Table 1. Genetic parameters for 18 characters in 64 barnyard millet germplasm accessions

S.No.	Characters	Range		Mean	Coefficient of variation (%)		Heritability (broad sense)%	Genetic advance as % of mean
		Minimum	Maximum		PCV	GCV		
1	Days to 50% flowering	41.0	72.5	49.0	15.5	14.3	85.0	27.1
2	Basal tillers	1.0	3.9	2.0	**32.6**	**30.3**	86.4	58.1
3	Days to maturity	81.0	112.5	89.1	9.3	6.9	55.2	10.6
4	Peduncle length (cm)	12.3	23.9	17.8	14.9	13.5	82.6	25.3
5	FLB Length(cm)	21.4	32.0	26.8	10.5	8.2	60.7	13.2
6	FLB Width(cm)	1.8	2.7	2.2	12.0	10.3	73.7	18.3
7	Plant height (cm)	90.9	158.4	117.6	12.6	11.0	76.6	19.9
8	Panicle length (cm)	13.5	26.3	18.4	16.9	15.7	86.0	30.0
9	1000 seed weight (g)	1.4	3.7	2.5	19.8	18.4	86.4	35.2
10	Panicle weight per plant (g)	8.0	17.0	10.4	17.9	16.3	82.9	30.5
11	Harvest Index(%)	30.2	38.9	33.6	7.8	5.1	41.3	6.8
12	Lower raceme length (cm)	1.9	6.0	3.3	28.6	27.4	92.0	54.1
13	Grain yield/plant (g)	6.5	15.0	8.9	19.8	15.7	63.1	25.7
14	Phosphorus mg/100g	253.0	296.0	276.0	**4.4**	**2.4**	28.5	2.6
15	Calcium mg/100g	16.0	24.0	19.6	13.3	11.6	75.7	20.8
16	Iron mg/100g	12.5	21.2	16.7	13.0	11.1	72.8	19.6
17	Zinc mg/100g	36.2	56.8	45.5	15.3	13.6	78.5	24.8
18	Protein %	6.8	11.9	8.6	16.2	14.1	75.5	25.2

FLB -Flag Leaf Blade

length, 1000 seed weight, lower raceme length, grain yield plant^{-1}, zinc, and protein content, high heritability and genetic advances as a percentage of mean were recorded.Higher estimates of PCV, GCV, genetic advance as a percent of mean and heritability were recorded for traits such as number of basal tillers plant^{-1} and lower raceme length, implying that these characters were primarily under the control of additive gene action and that genetic improvement could be achieved through simple selection for these traits.

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