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GAU Research Journal **46** (1) : 01 (January 2021)

Short Communication

First report of root-knot nematode (*Meloidogyne incognita*) infecting Tuberose (*Polianthes tuberosa* L.) in Gujarat

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SHORT COMMUNICATION

Plant parasitic nematodes are important biotic restrictions in the horticultural systems. Root-knot nematodes are a major economic pest in various crops. Tuberose (*Polianthes tuberosa* L.) is an important ornamental flowring crop in India and it has great economic value as a cut flower and in the perfume industry. It is grown in the states of Karnataka, Tamil Nadu, West Bengal, Maharashtra, Odisha and Utter Pradesh. Recently, during daily routine field visit it was observed that growth of some tuberose plants was reduced, having yellowing of leaves with reduced length of spikes. When such plants were pulled out along with root system, galls were noticed. Such galls were dissected, active juveniles and different stages of female of root-knot nematode were observed. The specific identity of the nematode was determined by cutting perineal patterns of the females. On the basis of perineal pattern and other characters such as stylet length, head shape and larval length (Eisenback, 1985), the nematode was identified as *Meloidogyne incognita*. This is a first report of *Meloidogyne incognita* infecting *P. tuberosa* in Gujarat.

ACKNOWLEDGEMENT

Authors are thankful to Project coordinator, AICRP on Nematodes in Agriculture, New Delhi for identification of nematode species.

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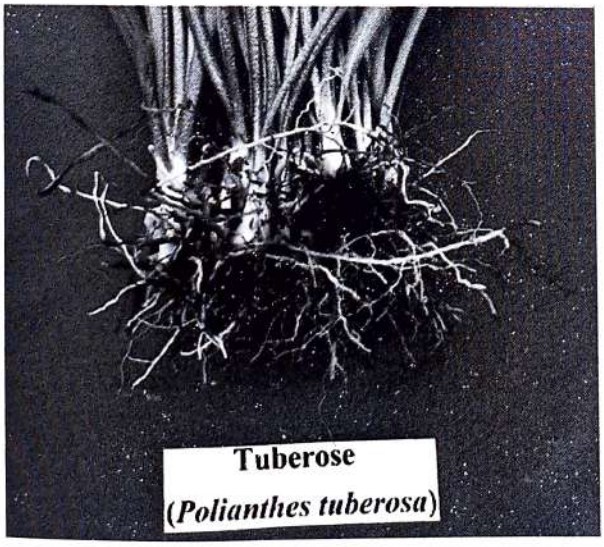
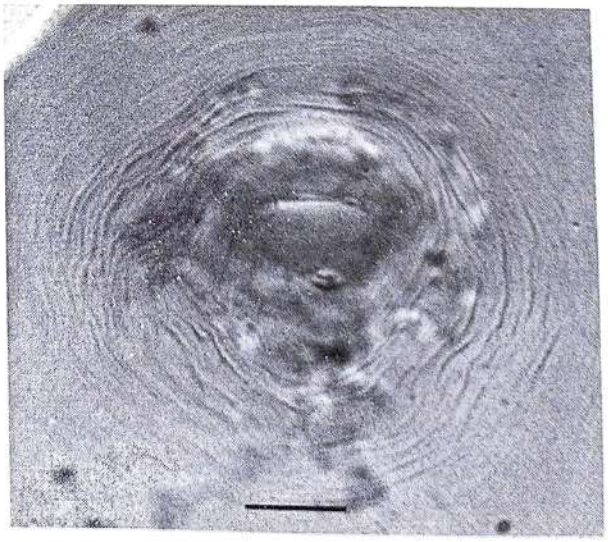


Infected plants



M. incognita

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Sequential application of insecticides for management of leaf eating caterpillar, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in bidi tobacco nursery

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ABSTRACT

An experiment was carried out for two years (2017-18 and 2018-19) in randomized block design at Bidi Tobacco Research Station, Anand Agricultural University, Anand, Gujarat (India) to evaluate the sequential application of insecticides for management of leaf eating caterpillar, *S. litura*. In tobacco nursery, use of neem seed kernel extract (NSKE) (500g 10 L^{-1} water) at the time of 30-35 days after seeding (DAS) followed by any of the recommended insecticide *i.e.* chlorpyrifos 50 % + cypermethrin 5 % EC at 0.055 % (10 mL 10 L^{-1} water, 275 g a.i/ha) or emamectin benzoate 5 % SG at 0.0025 % (5g 10 L^{-1} water, 12.5 g a.i/ha) or chlorpyrifos 20 % EC at 0.04 % (20 mL 10 L^{-1} water, 200 g a.i/ha) or quinalphos 25 % EC at 0.05% (20 mL 10 L^{-1} water, 250 g a.i/ha) 45 DAS, for effective and economical management of leaf eating caterpillar, *S. litura*.

In an experiment in laboratory with same insecticides used for field experiment were evaluated in completely randomized design for relative efficacy in order of the persistent toxicity. The highest toxicity up to ten days was registered in cholrpyriphos 50% + cypermethrin 5% EC followed by emamectin benzoate 5% SG, quinalphos 25% EC and chlorpyrifos 20% EC. The NSKE @ 5% registered least persistence toxicity.

Keywords: Leaf eating caterpillar, sequential spraying, insecticide resistance management (IRM)

Tobacco, *Nicotiana tabacum* L. is one of the important commercial crops grown in about 4.5 lakh hectares which is about 0.23% of cultivated land in India. India is the third largest producer of tobacco leaf in the world. Among the 13 growing states in the country Andhra Pradesh, Gujarat, Uttar Pradesh and Karnataka are major tobacco growing states (Patel *et al.,* 2019). Tobacco is also fairly important as an economic activity in India, its production and sale directly or indirectly involve 7 million workers, and tobacco contributes roughly 2 per cent of central tax revenue (John *et al*., 2010). The tobacco caterpillar, *S. litura* is a polyphagous regular pest of tobacco, which has high mobility and reproductive capacity (Holloway, 1989). The damage varies from 3 to 17 % in the tobacco nursery and under favorable conditions this loss may extent about 80 % which leads to wiped out entire nursery (Chari and Patel, 1972). The insecticides recommended by Central Insecticide Board (Anon., 2020c) for control of lepidopteran insect pest are *viz*., emamectin benzoate 5 % SG (Bhatt *et al.,* 2018), chlorpyrifos 20 % EC, quinalphos 25 % EC and chlorpyrifos 50% + cypermethrin 5% EC were used for experimentation as schedule spray (2 sprays, first at 30 DAS followed by 45 DAS) along with sequential spray of NSKE 5 % at 30 and 45 DAS either emamectin benzoate 5 % SG or chlorpyrifos 20 % EC or quinalphos 25 % EC or chlorpyrifos 50% + cypermethrin 5% EC. Leaf eating caterpillar, *S. litura* is an important pest worldwide and is exposed to insecticides throughout the year, resulting in the rapid development of resistance to organophosphorus compounds like quinalphos and chlorpyrifos (Ahmad *et al.,* 2008). The experiment was planned with a view to evaluate the efficacy and economics of sequential application of insecticides against *S. litura* under nursery condition and thereby reducing total cost and delay the development of resistance.

MATERIALS AND METHODS

Test insecticides

Emamectin benzoate 5 SG, quinalphos 25 EC, chlorpyrifos 20 EC, chlorpyrifos 50% + cypermethrin 5% were purchased from local market and used.

For NSKE, sufficient amount of neem (*Azadirachta indica* Juss) seeds was collected and kernels were separated from seeds then NSKE 5 % spray solution prepared by soaking kernels overnight in water (500 g 10 L^{-1} water). The dose of each synthetic

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insecticides applied, chlorpyrifos 50 % + cypermethrin 5 % EC at 0.055% (10 mL 10 L^{-1} water, 275 g a.i ha^{-1}), emamectin benzoate 5 % SG at 0.0025% (5g 10 L^{-1} water, 12.5 g a.i ha^{-1}), chlorpyrifos 20 % EC at 0.04% (20 mL 10 L^{-1} water, 200 g a.i ha^{-1}) and quinalphos 25 % EC at 0.05% (20 mL 10 L^{-1} water, 250 g a.i ha^{-1}).

Test Experiments :

Field experiment

Field experiment was carried out in nursery at Bidi Tobacco Research Station, Anand Agricultural University, Anand for two years (2017-18 and 2018-19) during *kharif* season in randomized block design with the eight treatments (Table 1) in addition to control (water spray) and absolute control (no spray). The size of bed was 1.2 × 1.2 m and seeding with cv. A 119 variety of bidi tobacco was done. The insecticidal treatments were imposed at initiation of the pest *i.e.* 30 and 45 days after seeding (DAS). Volume of spray used was 500 L ha^{-1}. Observations on germination count were taken at 10 DAS with the help of 10 quadrates (25 cm^2) from each bed. Healthy and damaged seedlings were counted at each pulling and finally total number of damaged and healthy transplantable seedlings was worked out. Incremental cost-benefit ratio (ICBR) *i.e.* net gain in rupees per rupee cost of insecticidal treatment was calculated by dividing net gain with the cost of treatment.

Nursery cum laboratory

With a view to determine persistent toxicity of insecticides a nursery cum laboratory experiment was carried out. The insecticides mentioned in table 2 were applied to tobacco nursery (at 30 days old seedlings) in separate beds at 1st, 5th and 10th day. After 11th day of application, required number of tobacco seedlings were pulled out from each bed and kept separate, of total 12 beds. These seedlings were brought to the laboratory for experimentation in completely randomized design. These insecticidal treated seedlings were kept in a plastic bowl (10 cm diameter x 6.5 cm deep) separately and ten larvae of third instar were released allowed to feed on it. Insecticidal treated seedlings kept in bowl covered with muslin cloth. The observations on the mortality were recorded after 24 hours of release. The per cent mortality was corrected by using Abbott's formula (Abbott, 1925). The number of days for which the toxicity persisted was recorded as 'P'. The average of the mortality percentage constituted the residual toxicity 'T'. The product of 'P' x 'T' was calculated. Based on the 'PT' value the order of relative efficacy (ORE) was worked out. Here, greater the 'PT' value, better was the treatment. The procedures of Saini (1959) which was elaborated further by Pradhan (1967) and Sarup *et al.* (1970) were adopted to calculate the persistent toxicity.

Statistical analysis

The data were analyzed as per ANOVA following appropriate transformation as suggested by Steel and Torrie (1960).

RESULTS AND DISCUSSION

Management of leaf eating caterpillar

The data on evaluation of scheduled spraying of insecticides for the management of leaf eating caterpillar, *S. litura* infesting bidi tobacco is presented in Table 1. The results revealed that germination counts were non-significant in the year 2017-18, 2018-19 and pooled indicate that uniform growth of seedlings before impose of the treatments. All the insecticidal treatments (T_1 to T_8) were significantly superior over the control (T_9 & T_{10}) for managing the seedling damage. The minimum per cent damaged seedlings ranged from 18.30 to 19.29 % (2017-18), 26.42 to 35.97 % (2018-19) and 22.23 to 26.67 % (pooled) were registered in the treatment scheduled (T_5 to T_8) with two sprays at 30 and 45 DAS of synthetic insecticides. The next best sequence (T_1 to T_4) for percent damaged seedling was ranged from 24.98 to 25.94 % (2017-18), 28.21 to 35.57 % (2018-19) and 26.57 to 30.66 % (pooled), where first spray of botanicals with NSKE 5% at 30 DAS and second spray of any synthetic insecticide either, emamectin benzoate 5 % SG or chlorpyrifos 20 % EC or quinalphos 25 % EC or cholrpyrifos 50% + cypermethrin 5% EC at 45 DAS was made. The maximum (> 54%) damaged seedlings were noticed in both control (T_9 and T_{10}).

Effect on healthy transplantable seedlings

The data on total number of healthy transplantable seedlings per bed on evaluation of schedule spraying of insecticides for the management of *S. litura* infesting bidi tobacco is presented in Table 1. All the insecticidal treatments (T_1 to T_8) were significantly superior over the control (T_9 & T_{10}) in registering the maximum total number of healthy transplantable seedlings. The maximum number of

healthy transplantable seedlings were in the range of 752 to 755 (2017-18), 475 to 623 (2018-19) and 615 to 693 (pooled) in the treatment (T_5 to T_8) scheduled with two sprays at 30 and 45 DAS of synthetic insecticides. Numerically, the next best sequence of the treatments (T_1 to T_4) registered total number of healthy transplantable seedling in the range from 633 to 665 (2017-18), 483 to 650 (2018-19) and 574 to 641 (pooled), where first spray of botanicals with NSKE 5% at 30 DAS and second spray at 45 DAS of any synthetic insecticide either, emamectin benzoate 5% SG or chlorpyriphos 20% EC or quinalphos 25% EC or cholrpyriphos 50% + cypermethrin 5% EC at 45 DAS were made. Minimum (< 500) number of healthy transplantable seedlings were noticed in both control (T_9 and T_{10}) in the year 2017-18, 2018-19 and pooled.

More or less similar results by Chaudhary and Shrivastava (2007) reported that quinalphos (0.04%) application was proved to be most effective followed by the application of Neem Seed Kernel Extract 5 % + Neem Leaf Extract 10 % reduced the maximum larval population. Among the neem products tested, NSKE 5 % showed the highest larval mortality of 40%. Insect growth regulatory effect was recorded in the NSKE 5 % (Razak *et al.*, 2014). All three insecticides, indoxacarb, methomyl and chlorpyriphos, had non-significant difference among themselves in reducing the larval population of *H. armigera* and *Spodoptera* spp. at 3, 5, 7 and 15 days following the application of the insecticides in Tobacco (Ahmed *et al.* 2004). Emamectin benzoate 5% SG found effective and economical for the control of leaf eating caterpillar infesting bidi tobacco seedlings (Bhatt *et al.,* 2018). The cypermethrin + chlorpyrifos mixture was significantly more toxic than cypermethrin + profenofos and cypermethrin + fipronil (Ahmad *et al.,* 2008).

Persistent toxicity

The persistent toxicity for each insecticide was also worked out and presented in the Table 2. In persistence studies, there was reduction in the mortality of larvae as the time increased. The combination of cholrpyriphos 50% + cypermethrin 5% EC (911.1) registered highest persistence toxicity (PT) followed by, emamectin banzoate 5% SG (799.9), quinalphos 25 % EC (744.4) and chlorpyrifos 20% EC (699.9) leads to prophylactic control up to 10 days against cut worm, *Agrotis ipsilon* Hufnagel, stem borer *Scrobipalapa heliopa* Lower and leaf eating cater pillar *Spodoptera litura* (Fabricius) after transplanting of bidi tobacco seedlings in field. In order of relative efficacy (OER) of the insecticide based on PT was, cholrpyriphos 50% + cypermethrin 5% EC > emamectin benzoate 5% SG > quinalphos 25% EC > chlorpyrifos 20% EC. The NSKE @ 5% registered less than 50% mortality of leaf eating caterpillar on 1 day after treatment with minimum persistence toxicity.

Our above results were in close proximity with Thibaud *et al.* (2003) revealed that in the resistant strain, the organophosphorus insecticides significantly increased the toxicity of pyrethroids suppressing the resistance effect, either by additive or synergistic effects. Chlorpyrifos, profenofos and fipronil could be used in mixtures to restore cypermethrin and deltamethrin susceptibility. These findings may have considerable practical implications for *S. litura* resistance management (Ahmad *et al.,* 2008). Emamectin benzoate 5 % SG @ 0.0025% and chlorfenapyr 10 % SC @ 0.01% were the most persistent insecticides, which gave cent per cent mortality of *S.litura* till 6 DAS in tobacco nursery (Sreedhar, 2010).

Economics

The economics worked out for the different treatments are presented in Table 3. The maximum ICBR worked out was 1:127 and 1:107 for the schedule of spray of chlorpyrifos 50% + cypermethrin 5% EC at 30 and 45 DAS (T_8) and NSKE 5% @ 30 DAS & chlorpyrifos 50% + cypermethrin 5% EC (T_4) respectively. The cost of insecticides were comparatively less in a treatment sequences with NSKE 5% at 30 days and synthetic insecticide either chlorpyrifos 50% + cypermethrin 5% EC or emamectin benzoate 5% SC or chlorpyrifos 20% EC or quinalphos 25% EC rather than single synthetic insecticidal spray scheduled at 30 and 45 DAS.

The insecticide mixtures may offer benefits for insecticide resistance management when appropriately incorporated into rotation strategies with additional modes of action (Anon., 2020a). The Mode of Action (MoA) describe by Insecticide Resistance Action Committee (IRAC) for chlorpyrifos and quinalphos belongs to organophosphurus (Group 1B) which is Acetylcholinesterase (*AChE*) inhibitors and cypermethrin have its place in to pyrethroid (Group 3 Sodium channel modulators). For NSKE (*Azadirachtin*) as antifeedant. Emamectin benzoate inhibits muscle contraction, causing a continuous flow of chlorine ions in the GABA and H-Glutamate receptor sites (Group 6 Glutamate-gated

Table 1 Evaluations of schedule spraying of insecticide on *Spodoptera litura* (F) infesting tobacco nursery

Treatment Detail		Germination count 25 cm2			Damaged seedlings (%)			Total number of healthy transplantable seedlings bed-1		
		2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
T1	NSKE 5% @ 30 DAS & Emamectin 5% SG @ 45 DAS	11.97	11.96	11.97	30.63 (25.95)*	32.93 (29.55)*	31.78 (27.74)*	665	608	637
T2	NSKE 5% @ 30 DAS & Chlorpyrifos 20% EC @ 45 DAS	11.83	10.80	11.32	30.42 (25.63)	36.22 (34.91)	33.32 (30.17)	660	533	597
T3	NSKE 5% @ 30 DAS & Quinalphos 25% EC @ 45 DAS	11.53	12.03	11.78	30.62 (25.94)	36.61 (35.57)	33.62 (30.66)	665	483	574
T4	NSKE 5% @ 30 DAS & Cholrpyrifos 50% + Cypermethrin 5% EC	11.87	12.76	12.32	29.99 (24.98)	32.08 (28.21)	31.03 (26.57)	633	650	641
T5	Emamectin 5% SG @ 30 DAS & Emamectin 5% SG@ 45 DAS	11.83	10.83	11.33	26.06 (19.29)	32.75 (29.27)	29.41 (24.11)	755	575	665
T6	Chlorpyriphos 20% EC @ 30 DAS & Chlorpyrifos 20% EC @ 45 DAS	10.60	10.47	10.54	25.83 (18.98)	35.64 (33.95)	30.74 (26.13)	755	475	615
T7	Quinalphos 25% EC @ 30 DAS & Quinalphos25% EC @ 45 DAS	11.80	11.96	11.88	25.58 (18.64)	36.85 (35.97)	31.22 (26.67)	754	533	643
T8	Cholrpyrifos 50% + Cypermethrin 5% EC @ 30 DAS & Cholrpyrifos 50% + Cypermethrin 5% EC @ 45 DAS	11.73	11.57	11.65	25.33 (18.30)	30.93 (26.42)	28.13 (22.23)	752	633	693
T9	Control (Water spray)	11.77	13.07	12.42	48.81 (56.63)	50.58 (59.68)	49.70 (58.17)	498	350	424
T10	Control (No spray)	13.20	11.03	12.12	49.97 (58.63)	47.67 (54.65)	48.82 (55.35)	491	341	417
	S.Em ±	0.84	0.73	0.44	0.64	2.27	2.02	28.50	40.62	41.38
	CD @ 5%	NS	NS	NS	1.9	6.73	6.46	84.69	121	132
	CV%	12.32	10.85	10.35	3.44	10.55	8.30	7.44	13.57	10.28

*Arc sin transformation. The values given in parenthesis are retransformed values.

Note: First spray was be given @ 30 Days after sowing (DAS) and second spay @ 45 DAS.

Table 2 Persistence toxicity of synthetic insecticides against *S. litura* in bidi tobacco nursery

Insecticides	% mortality of S. litura in laboratory			P	T	PT	OER
	1 DAS	5 DAS	10 DAS				
Chlorpyrifos 50% + Cypermethrin 5% EC	96.67	93.33	83.33	10	91.11	911.1	1
Emamectin banzoate 5 SG	90.00	76.66	73.33	10	79.99	799.9	2
Chlorpyrifos 20 EC	83.33	63.33	63.33	10	69.99	699.9	4
Quinalphos 25 EC	86.67	70.00	66.67	10	74.44	744.4	3
Neem 5 %	46.33	-	-	-	-	-	-
S.Em ±	3.85	7.32	5.64				
CD @ 5%	11.50	22.03	16.93				
CV %	7.78	19.53	15.87				

DAS = Days after spray, P=Period of toxicity persistence (days), T=Mean per cent mortality, PT= Persistence toxicity, OER= Order of relative efficacy

Table 3 Economics of effective treatments

Treatment No.	Detail	Quantity of insecticide require (lit.or kg ha^{-1}	Cost of insecticide (Rs. lit.or or kg ha^{-1})	Total cost of treatment + labour charge	Total transplantable seedlings (TP) @7000 sq.mt	Gross income	Net gain over control (No. of TP ha^{-1})	Realization over control	ICBR
T_1	NSKE 5% @ 30 DAS & Emamectin 5%SG @ 45 DAS	25 + 0.250	926	2798	3654	730800	1222	244400	1:87
T_2	NSKE 5% @ 30 DAS & Chlorpyrifos20%EC @ 45 DAS	25 +1.000	436	2308	3425	685000	993	198600	1:86
T_3	NSKE 5% @ 30 DAS & Quinalphos 25%EC @ 45 DAS	25 +1.000	626	2498	3293	658600	861	172200	1:68
T_4	NSKE 5% @ 30 DAS & Cholrpyrifos 50% + Cypermethrin 5% EC	25 +0.500	451	2323	3677	735400	1245	249000	1:107
T_5	Emamectin 5%SG @ 30 DAS & Emamectin 5%SG @ 45 DAS	0.500	1500	3372	3815	763000	1383	138300	1:41
T_6	Chlorpyrifos 20%EC @ 30 DAS & Chlorpyrifos 20%EC @ 45 DAS	2.000	520	2392	3528	705600	1096	219200	1:91
T_7	Quinalphos25%EC @ 30 DAS & Quinalphos25%EC @ 45 DAS	2.000	900	2772	3689	737800	1275	251400	1:90
T_8	Cholrpyrifos 50% + Cypermethrin 5% EC @ 30 DAS & Cholrpyrifos 50% + Cypermethrin 5% EC @ 45 DAS	1.000	550	2422	3976	795200	1544	308800	1:127
T_9	Control (Water spray)	-	-	-	2432	486400	-	-	-
T_{10}	Control (No spray)	-	-	-	2392	478400	-	-	-

chloride channel allosteric modulators, Nerve and muscle action) (Anon., 2020b). A key element of effective resistance management is the use of alternations, rotations, or sequences of different insecticide MoA classes. Users should avoid selecting for resistance or cross-resistance by repeated use within the crop cycle, or year after year, of the same insecticide or related products in the same MoA class (Anon., 2020a).

CONCLUSION

The bio efficacy of the recommended insecticides remains at par with each other in the treatment of two sprays with same synthetic insecticides @ 30 & 45 DAS. The sequential spray with NSKE 5% @ 30 DAS coupled with synthetic insecticides @ 45 DAS were equally effective. Among the recommended insecticides, use of neem seed kernel extract (500 g 10 L^{-1} water) at the time of 30-35 days after seeding followed by any of the synthetic insecticide at 45 days after seeding, helped in delaying the development of resistance in leaf eating caterpillar, *S. litura*. The cost of single synthetic insecticides at 30 and 45 DAS was more as compared same insecticide coupled with NSKE 5 % @ 30 DAS. The field cum laboratory with same insecticides suggest that in order of relative efficacy of the insecticide based on PT was highest in cholrpyriphos 50% + cypermethrin 5% EC followed by emamectin benzoate 5% SG, quinalphos 25% EC and chlorpyrifos 20% EC. The toxicity of NSKE @ 5% only persisted up to one day by registering below 50% mortality of test insect.

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Price forecasting of agricultural commodities in electronic-national agriculture market: using ARIMA model

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ABSTRACT

The present research aims to predict the monthly modal prices of randomly selected rice, red gram and groundnut agricultural commodities in e-NAM (electronic-National Agriculture Market) mandi. The Auto Regressive Integrated Moving Average (ARIMA) model was identified by the Partial Auto Correlation Function and Auto Correlation Function at various lags. The selected model was tested by AIC, BIC and MAPE criterion at 95% confidence interval. The monthly data from August 2016 to November 2019 have been collected from e-NAM portal to predict the prices for the next 12 months using statistical R software. The order of the best ARIMA model was found to be $(0,0,1)(1,1,0)_{[12]}$; $(1,0,0)_{[12]}$; and (0,1,0) with the predicted monthly modal market prices- Rs 2,610 per quintal, Rs 4950 per quintal, and Rs 5,883 per quintal for rice, red gram and groundnut respectively. The result of the study intends to help the farmers in gaining maximum benefit in terms of a better price at less cost of production.

Keywords: Farmers, Auto Regressive Integrated Moving Average (ARIMA) model, e-NAM, electronic-National Agriculture Market, Agricultural Product, Price Forecasting.

"Improving the lives of billions of people at the bottom of the economic pyramid is a noble endeavor. It can also be a lucrative one."
- C.K. Prahlad

The agriculture sector has played a vital role in enhancing the growth of the Indian economy throughout the past years. In India, two-third of the population is directly or indirectly linked with the agriculture and its allied sector. With the introduction of the green revolution in India, the production of food grains and pulses has been increased and still increasing due to growing demand and the rising population of the country. As per the Food and Agriculture Organisation (FAO) -2019 statistics, India is ranked among the top five largest producers' country in most of the agricultural commodities. In the past few decades, Indian agriculture has flourished tremendously in terms of production and productivity. India is one of the leading exporters of rice, wheat, groundnut, cotton, pulses (including pigeon pea, red gram, black gram, cowpea), potatoes, onions, fruits (citrus), tobacco, and sugarcane. India has attained the self-sufficiency of food but not able to realise enough farmers' income. The present marketing system is highly dominated by middlemen and as a result, farmers are not able to earn remunerative prices for their commodities, in return, they must migrate to other sectors for earning daily wages. The present scenario demands an efficient marketing system for selling agricultural commodities with better price discovery in the regulated market.

Past few years, area, production, and productivity have increased with higher price fluctuations in agricultural products due to imperfect markets (Darekar & Reddy, 2018). The prices of agricultural commodities have shown irregularities in prices over a period. It is evident that year after year production of rice, gram, and groundnut in India from 1950 to 2019 are varied tremendously. The production of rice, gram, and groundnut has increased many folds but after some decades, the production increased with a diminishing rate (Source: Directorate of Economics and Statistics, 2019). For sustained production and better price discovery, price forecasting of agricultural commodities is consequential thing (Darekar & Reddy, 2017). The research problem for this study is the fluctuation of the commodity prices, which create hindrances in farmers income and marketing decision.

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Considering these points, the present study examines the price forecasting of commodities in an e-NAM implemented mandi.

The author has randomly selected, Suryapet mandi of Telangana State, which is one of the best e-NAM implemented mandis in India. In Suryapet mandi, e-NAM was implemented in August 2016. The mandi has accepted the maximum number of traded commodities in the e-NAM platform. The major commodities brought by farmers were rice, gram, groundnut, cotton, paddy, maize and turmeric. The prices of favorable commodities were showing fluctuations over a period and farmers do not understand which crop to consider for sowing in next season for better prices. To get a proper solution; farmers, entrepreneurs, policymakers, traders, and investors must understand the future and present market scenario. Based on this information, they will provide them better production and marketing decisions. In this competitive market, forecasting commodity prices and production inputs in planning has a great significance over determining the market price (Seyed *et al. 2015*).

In Malaysia, Assis *et al.* (2010) studied various forecasting methods for predicting cocoa bean prices and found that the ARIMA Model is the best suited model. Using the ARIMA model, the palm oil trend prices forecasted in Thailand by Nochai & Nochai (2006); Masuda & Goldsmith (2009) have predicted monthly production of Soybean; Cooray (2006) has applied this model for calculating the monthly production of tea and paddy in Sri Lanka.Burark & Sharma (2012) have established univariate ARIMA models to predict future prices for agricultural products. Therefore, author has randomly selected three commodities i.e. rice, red gram and groundnut based on prolonged holding property from the various available commodity.

This paper is organised in three sections. The first part describes the introduction of the research. In the second section, material and methods are discussed. In the last section, results and discussion of the model are presented systematically with graphs and tables.

MATERIALS AND METHODS

The research aims to predict the future prices of agricultural products and for that purpose various forecasting techniques has been adopted. The author has studied various literature and found that the most frequently used technique was the ARIMA model by Box-Jenkins (1970). Various detailed literature helped the researcher in selecting an appropriate method and obtaining better results. The author has studied other forecasting models (like linear regression and exponential) also but after comparing, ARIMA model has accurate and appropriate results. ARIMA model is the best suited for discovering patterns and predicting future values (Darekar & Reddy, 2017; Assis *et al.*, 2010; Kumar *et al.*,2011). This study tries to forecast the agricultural product prices in e-NAM mandi that can help the farmers in obtaining remunerative prices at the right time. The researcher has focused on the existing gap between the existing and estimated priceof agricultural commodities. This study will help farmers, investors and entrepreneurs to decide when they can store and sell the crops for better realisation.

Data collection:

The present study has considered the past 40 months data (from August 2016 to November 2019) collected from the e-NAM platform for predicting the agricultural commodities prices for the next 12 months i.e. for December, 2019 to November, 2020.

price

Time series analysis:

ARIMA model is one of the methods used in forecasting variables and from variables itself to forecast its trend. It is popularly known as Box-Jenkins (1976) methodology. The B-J model is best suited to the recent past data for short term forecasting (Darekar& Reddy, 2017; Divya, 2015). The model is characterised by "ARIMA (p, d, q)" where notation 'p' denotes orders of auto-regression, 'd' denotes integration (differentiation), and 'q' denotes moving average. Most of the time series data are not stationary then by creating a new time series of "successive differences" (Z_t-Z_{t-1}) will be created until the time series is not made stationary. To check this ADF (Augmented Dickey-Fuller) and PP (Phillips Perron) tests are applied to make series stationary. It is assumed that Ho: unit root, in the data series. Thus, if calculated statistics is greater than the tabulated value, then the null hypothesis is rejected.

Box & Jenkins (1976) have developed *three- stage iterative cycle* to study the large data set for selecting the best model that is fit for forecasting:

i.Identification: The time series data is non-stationary, so first order differencing would be performed to make data stationary. After exhibiting first order differencing, seasonality in data was

removed using Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF).The general representation of the AR model where p shows its past value is known as AR(p) model:

$Z_t=\mu+\emptyset_1 Z_{t-1}+\emptyset_2 Z_{t-2}+\ldots\ldots\ldots\ldots\emptyset_p Z_{t-p}+e_t$

The general representation of the MA model where q shows its past value is known as MA(q) model:

$Z_t=\mu+e_t-1Q_1e_{t-1}-Q_2e_{t-2}-\ldots\ldots\ldots\ldots-Q_qe_{t-q}$

In Autoregressive Integrated Moving Averages model, time series represented as a mix of both AR and MA models which is referred as (p, d, q) is

$Z_t=\mu+\emptyset_1 Z_{t-1}+\emptyset_2 Z_{t-2}+\ldots.+\emptyset_p Z_{t-p}+\mu-Q_1e_{t-1}-Q_2e_{t-2}-\ldots\ldots\ldots-Q_qe_{t-q}+e_t$

Where, Z_t is commodity prices for rice, red gram and groundnut, e_t (for t = 1, 2,... n) is normally distributed with mean = 0 and variance = constant; d is the difference between AR and MA; $\emptyset_p$ and Q_q are coefficients to be evaluated.*Estimation:* In the second stage, the model was checked for fit and accuracy. For the goodness of fit, adjusted R-square was analysed. To check the accuracy of the model values of MSE (Mean Square Error), MAPE (Mean Absolute Percent Error) and RMSE (Root Mean Square Error) were taken into consideration.

ii. Verification: The best model was verified by using the Akaike Information Coefficient (AIC) and Bayesian Information Criterion (BIC). Lesser the values AIC and BIC, the model would be efficient in predicting future prices. The selected best fit models were validated by applying Ljung-Box statistics.

iii. Forecasting: The best suited time series ARIMA model was used for making forecasts for future values. The "d-value" affects the prediction intervals of the model and as the values of "d" increases, the prediction intervals also increases. Burark& Sharma (2012) have established univariate ARIMA models to predict future prices for agricultural products. Mohapatra, *et al.* (2018) has found ARIMA as a fitted model for forecasting the monthly price of groundnut in Odisha. In Karnataka, Punitha (2007) have studied the Box-Jenkins ARIMA model for maize and groundnut to predict the price and arrival quantity in Hubli and Devangere markets.

RESULTS AND DISCUSSION

Before identifying forecasting model, the time series data should be stationary in nature. To check this ADF (Augmented Dickey-Fuller) and PP (Phillips Perron) tests are applied. The result shows that unit root (non-stationary) is present in series. Therefore, Ho is not rejected at the 5% significance level and concludes that the series is non stationary. To make the data stationary 1st order differencing was applied. Table 1 shows critical values and test staticsvalues when data was non-stationary and made stationary.

Table 1 Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) test of stationarity

Agricultural Commodities	Test used	Test-statistic (at level)	Test critical values at 5% level	Test-statistic (1st diff.)	Test critical values at 5% level
Rice	ADF	-3.987	-3.500	-5.682	-3.500
	PP	-3.429	-3.528	-6.806	-3.531
Red gram	ADF	-3.533	-3.500	-4.519	-3.500
	PP	-3.447	-3.528	-7.372	-3.531
Groundnut	ADF	-2.304	-3.500	-5.039	-3.500
	PP	-3.635	-3.528	-7.285	-3.531

1) Identification: ACF helps in choosing AR terms i.e. q and PACF helps in choosing MA terms i.e. p values, which are obtained by looking for considerable spikes in ACF and PACF respectively with 20 lags. The residuals of ACF and PACF indicates (in below Graph 1) ARIMA$(0,1,0)(0,1,1)_{[12]}$, ARIMA$(0,1,0)(0,1,0)_{[12]}$,and ARIMA(0,1,0) are the good fit identified models. After exhibiting first order differencing, seasonality in data was removed using Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF). Each coefficient of ACF and PACF are found statistically significant. The figure shows that the correlogram of the residuals is flat it means that all the information has been captured, so the forecast can be done by this model. However, theseries is found to be stationary since, the coefficient dropped to zero after the second lag.

Graph 1: Residuals of ACF and PACF

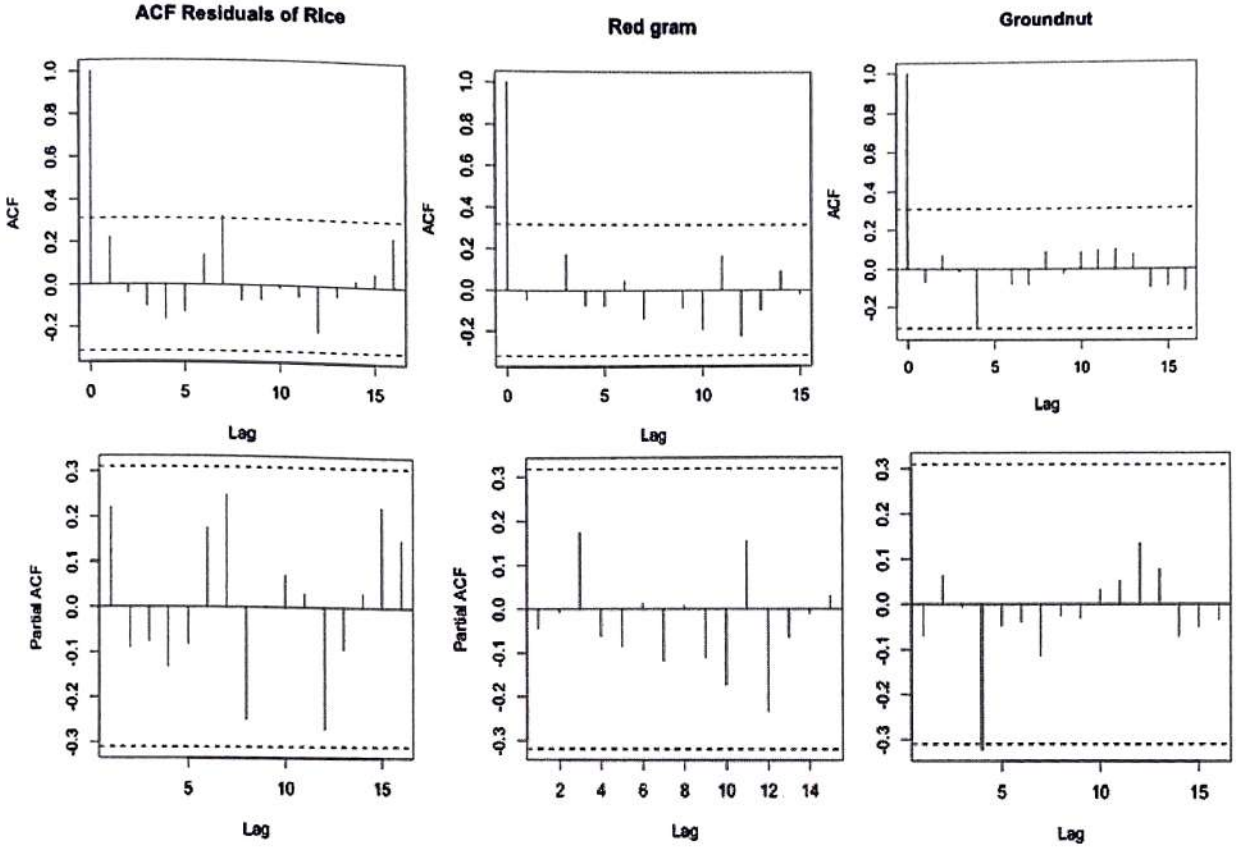


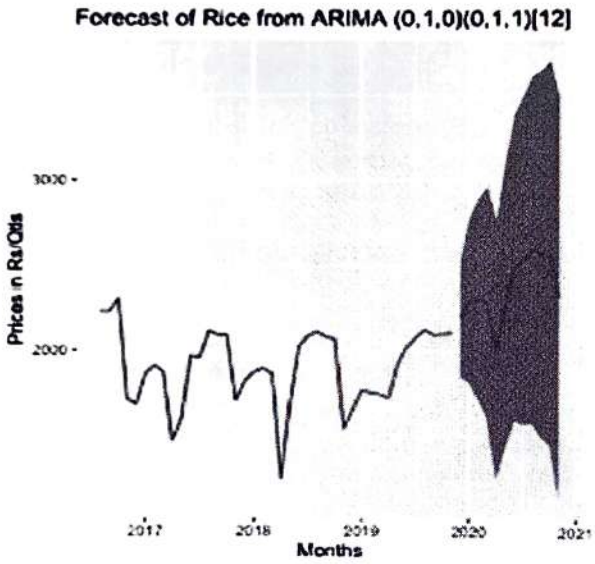
Table 2 Values of MSE, MAPE, RMSE, Adjusted R square, AIC and BIC

Commodity	ARIMA Model	MSE	MAPE	RMSE	Adjusted R square	Akaike Information Coefficient (AIC)	Bayesian Information Criterion (BIC)
Rice	ARIMA (0,1,0) (0,1,1) [12]	71.71	3.96	138.68	0.81	361.45	364.04
Red Gram	ARIMA (0,1,0) (0,1,0) [12]	226.76	5.42	428.63	0.83	416.5	417.5
Groundnut	ARIMA (0,1,0)	440.94	10.62	668.86	0.84	440.54	441.83

1) Estimation: The most appropriate model should have the least values of MSE, MAPE and RMSE and the highest adjusted R-square value. The selected "ARIMA$(0,1,0)(0,1,1)_{[12]}$, ARIMA$(0,1,0)(0,1,0)_{[12]}$, and ARIMA(0,1,0)" model for rice, red gram and groundnut has least values of MSE (71.71; 226.76; 440.94), MAPE (3.96; 5.42; 10.62) and RMSE (138.68; 428.63; 668.86) respectively among other models with the highest adjusted R-square value is 0.81, 0.83, 0.84 respectively shown in Table 2.

2) Verification: The values of the AIC and BIC of the "ARIMA$(0,1,0)(0,1,1)_{[12]}$, ARIMA$(0,1,0)(0,1,0)_{[12]}$, and ARIMA (0,1,0)" shows least statistic values, hence the results in Table 2 shows that model would be efficient and accurate in predicting future prices. The author has applied Ljung-Box statistics which shows that p value is insignificant, and the model is free of auto correlation.

Forecasting: The forecast prices and actual prices are compared at 95% confidence interval and it is found that ARIMA$(0,1,0)(0,1,1)_{[12]}$, ARIMA $(0,1,0)(0,1,0)_{[12]}$ and ARIMA (0,1,0) model is the best price fit forecast model for rice, red gram, and groundnut respectively. The forecast shows that the modal monthly market price of rice, red gram, and groundnut would be Rs 2,610 per quintal, Rs 4950 per quintal, Rs 5,883 per quintal for the next 12 months. The modal monthly prices are varying throughout the year, but farmers can gauge future prices in advance using the forecasted prices. During August and September, the price of rice, red gram, and groundnut in the market would be higher and it is predicted that it would be favorable time for selling the commodities.



Graph 2

The maximum monthly modal price for rice is in the month of September and October. The lowest predicted price is in month of November. Rice is grown in both the summer and winter season, but the farmer has to decide when to bring the produce and get remunerative prices for the same produce. The maximum monthly model price for red gram is in the month of October and November and lowest in the month of November. This shows that if the supply has been increased at the same time, the demand for that produce will surely be going to be less. Likewise, groundnut, the maximum monthly model price for groundnut is in month of October and November, and the lowest price in the month of November. The price forecast of Rice, Red gram and Groundnut for the next 12 months are shown in Graph 2-4 with Table 4-6.

Table 4: Price Forecast for Rice

Month	Forecast Value	95% confidence interval	
		Low	High
Dec 2019	2185.18	1845.04	2525.32
Jan 2020	2293.32	1812.28	2774.35
Feb 2020	2303.88	1714.73	2893.02
Mar 2020	2282.14	1601.86	2962.43
Apr 2020	2004.21	1243.63	2764.80
May 2020	2259.68	1426.50	3092.86
Jun 2020	2486.30	1586.36	3386.23
Jul 2020	2530.84	1568.77	3492.91
Aug 2020	2592.79	1572.36	3613.22
Sep 2020	2568.90	1493.95	3643.85
Oct 2020	2571.02	1447.18	3700.86
Nov 2020	2314.35	1137.91	3490.80

So, ultimately the farmers are advised to decide as per the predicted prices done by the ARIMA model in the present study, whether to bring their produce in the market or to store their produce. The farmers of Suryapet Mandi can fetch maximum remunerative price (i.e. Rs 10,484 per Quintal) by selecting groundnut from three selected commodities as per the forecasting model. As per the Biswal & Sahoo, (2018) have compared the actual and expected market price and the study suggests, the forecasted price of the commodities extracted from the model is always lower than the actual market price. This shows that groundnut is a good cash crop among three of the commodities and has highest monthly modal price for upcoming months.

The result of this analysis will help in discovering the minimum price for their commodity before harvesting and they can take advantage of market price fluctuation by quoting a reasonable price. Hence, farmers are advised to select and schedule their crops for cultivation, marketing and storage decisions accordingly.

Graph 3

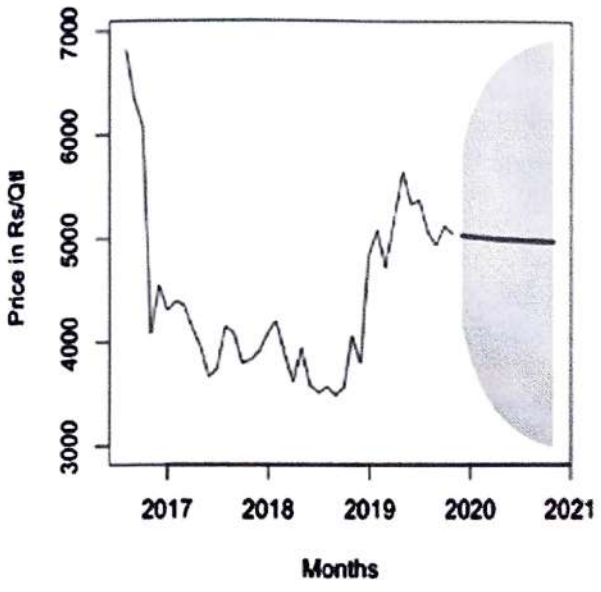


Table 4: Price Forecast for Redgram

Month	Forecast Value	95% confidence interval	
		Low	High
Dec 2019	5013.75	4135.72	5891.79
Jan 2020	5005.37	3820.22	6190.52
Feb 2020	4997.77	3610.19	6385.35
Mar 2020	4990.88	3456.80	6524.97
Apr 2020	4984.64	3339.88	6629.39
May 2020	4978.97	3248.55	6709.40
Jun 2020	4973.84	3176.06	6771.62
Jul 2020	4969.19	3117.88	6820.50
Aug 2020	4964.97	3070.80	6859.14
Sep 2020	4961.14	3032.46	6889.83
Oct 2020	4957.67	3001.08	6914.27
Nov 2020	4954.53	2975.29	6933.78

Graph 4

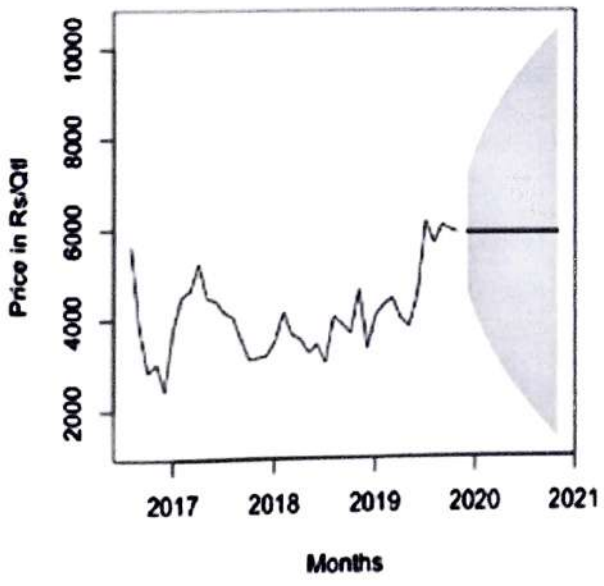


Table 5: Price Forecast for Groundnut

Month	Forecast Value	95% confidence interval	
		Low	High
Dec 2019	5883.00	4554.77	7211.23
Jan 2020	5883.00	4004.60	7761.40
Feb 2020	5883.00	3582.44	8183.56
Mar 2020	5883.00	3226.54	8539.46
Apr 2020	5883.00	2912.99	8853.01
May 2020	5883.00	2629.51	9136.49
Jun 2020	5883.00	2368.83	9397.17
Jul 2020	5883.00	2126.20	9639.80
Aug 2020	5883.00	1898.31	9867.69
Sep 2020	5883.00	1682.77	10083.23
Oct 2020	5883.00	1477.76	10288.24
Nov 2020	5883.00	1281.88	10484.12

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Comparison of selection indices using different weights in maize (*Zea mays* L.) for different biometrical characters

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ABSTRACT

The data on six different biometrical characters of fifty seven genotypes/hybrids of maize were collected from Main Maize Research Station (MMRS), A.A.U., Godhara during *Rabi* season of the year 2015-16 for the present study entitled "Comparison of selection indices using different weights in maize (*Zea mays* L.) for different biometrical characters". The experiment was conducted in randomized block design with three replications. Six characters grain yield per plant, cob height, cob length, number of grains per row, number of rows per cob and 100 kernel weight were used. The selection index technique was employed to study the crop improvement using different characters giving different weights to each character. Selection index for all possible combination of six characters can be calculated and the combination which provides the higher relative efficiency is selected. Selection index for all possible combination of six characters which provides the high percent relative efficiency (PRE) is selected. For this present investigation, three different weights i.e. equal weight, genotypic correlation and phenotypic correlation were given to different characters to construct selection indices to select the optimum index in maize. Total 63 selection indices were constructed for each weight method. In general higher per cent relative efficiency (PRE) was observed for equal weight method among all three weight methods. The selection index (I_{12346}) having grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight had the highest per cent relative efficiency (PRE) among all the combinations of selection indices in equal weight, genotypic correlation coefficient and phenotypic correlation coefficient weight methods. The rank correlation among different methods for selection index values were found positive and highly significant indicating agreement with all methods except equal weight. Therefore index based on equal weight taken is considered better than all other indices. The selection index without grain yield $I_{2346} = 0.492\,X_2+2.275X_3+0.649X_4+1.125X_6$ is the best indices.

Where, X_2 = cob height (cm), X_3 = cob length (cm), X_4 = number of grains per row and X_6 = 100 kernel weight (g)

Keywords: selection index, genotype, equal weight, genotypic correlation, phenotypic correlation

The data of large scale varietal trial having fifty seven genotypes/hybrids of maize were collected from Main Maize Research Station (MMRS), A.A.U., Godhara during *Rabi* season of the year 2015-16 and selection index technique was employed to study the crop improvement using different characters giving different weights to each character. The data on grain yield per plant (X1), cob height (X2), cob length (X3), number of grains per row(X4), number of rows per cob (X5) and 100 kernel(X6) were used for this analysis.

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MATERIALS AND METHODS

List of genotypes studied with their name

Sr. No.	Genotypes	Name of genotype
1	S3-25-1	P1
2	S4-06-1	P2
3	S4-22-5	P3
4	S4-44-5	P4
5	S4-70-1	P5
6	S4-70-2	P6
7	S3-17-1	P7
8	LM-5	P8
9	HKI-163	P9
10	CLQ-47	P10

Let us assume that economic value of a plant is determined by different variables and the merit of a plant is H. Then

$H = a_1G_1 + a_2G_2 + a_3G_3 + \ldots\ldots\ldots\ldots + a_nG_n = \sum_{i=}^{n} b_iX_i$

$I = b_1x_1 + b_2x_2 + b_3x_3 + \ldots\ldots\ldots\ldots + b_nx_n$ .... (1)

$H = a_1G_1 + a_2G_2 + a_3G_3 + \ldots\ldots\ldots\ldots + a_nG_n$ ... (2)

These I and H were estimated in such way that regression of I on H was maximized.

Thus, $\mathbf{b = X^{-1} x G x a}$

Selection index was calculated by substituting value of the character and b_i values in following equation

$I = b_1x_1 + b_2x_2 + b_3x_3 + \ldots\ldots\ldots\ldots + b_nx_n$

Selection index for all possible combination of six characters can be calculated and the combination which provides the higher relative efficiency is selected. Genetic gain and percent relative efficiency (PRE) were calculated by using the following formulae. Selection index for single or combination of characters which provides the high PRE is selected

The expected genetic advance is calculated as

$= (Z/P)((\sum\sum a_i b_i G_{ij}) / (\sum\sum b_i b_j p_{ij})^{½})$

Where Z/P = Selection intensity i.e. 2.06 at 5% level of significance.

Percent Relative efficiency (PRE)

$$PRE = \frac{\text{Genetic gain of selection index}}{\text{Genetic gain of grain yield}} \times 100$$

Equal weight

In equal weight, a value of 1 was assigned for all characters to construct selection indices.

$a_1 = a_2 = a_3 = \ldots = a_6 = 1$

Genotypic and phenotypic correlation coefficient

The genotypic correlation and phenotypic correlation were worked out between different yield contributing characters and yield as per suggested by Hazel *et al.* (1943) using SPAR1 software. These correlation coefficients were used as weight for selection index.

Genotypic correlation coefficient	Phenotypic correlation coefficient
$r_{gigj} = \frac{\hat{\sigma}_{gigj}}{\sqrt{\hat{\sigma}^2_{gi} \times \hat{\sigma}^2_{gj}}}$	$r_{pipj} = \frac{\hat{\sigma}_{pipj}}{\sqrt{\hat{\sigma}^2_{pi} \times \hat{\sigma}^2_{pj}}}$

Where,

r_{gigj} and r_{pipj}=Genotypic and phenotypic correlation coefficient between i^{th} and j^{th}character. ^gi2σand gj2^σ= Genotypic variances of i^{th} and j^{th} characterpi2^σand*pj*2^σ= Phenotypic variances of i^{th} and j^{th} character, respectively.

σ_{gigj} and σ_{pipj}=Genotypic & Phenotypic covariance between i^{th} and j^{th}character.

RESULTS AND DISCUSSION

Mean, range and coefficient of variation

The results presented in Table 1 revealed that the highest grain yield per plant was recorded by genotype/hybrid S4-22-5(P3) X CLQ-47 (P10) and it was highly significant compared to other genotypes. The value of broad sense heritability was 92.75 % which was second highest after 100 kernel weight. The maximum cob height was recorded for the genotype S4-70-2 (P6) X LM-5 (P8). The maximum cob lengths were recorded for genotype S4-44-5(P4) X S3-17-1(P7) and S3-25-1(P1) X S4-06-1(P2). The maximum number of grains per row were found for the genotype S4-22-5(P3) X CLQ-47 (P10). The highest number of rows per cob were recorded for genotype S3-25-1(P1) X S4-70-1 (P5) and S4-70-1(P5) X HKI-163 (P9).The maximum 100 kernel weight was recorded for genotype S4-22-5 (P3) X HKI-163 (P9). These results are in accordance with Hussain *et al.* (2016) and Ferdoush *et al.* (2017) in maize.

Genotypic and Phenotypic correlation coefficients

The correlation coefficients between grain yield per plant and its component traits among themselves were estimated at genotypic and phenotypic levels. The results of genotypic and phenotypic correlation coefficients between grain yield per plant and its components are given in Table 2.

Positive and significant genotypic correlation between grain yields with all the characters was observed. 100 kernel weights had the highest genotypic correlation with grain yield followed by number of grain per row. Similar trend was also observed for phenotypic correlation with yield. Cob height had also significant genotypic correlation with number of grains per row (0.3238), number of rows per cob (0.3557) and cob length (0.4292).Significant and positive phenotypic correlation of grain yield was found with all the character except cob height (0.1898). Cob height was found phenotypically non significant with all the character. The results of remaining characters observed that positive and significant correlation of cob length with number of grain per row, number of rows per cob and 100 kernel weight, while number of grain per row with 100 kernel

Table 1 Mean, range and coefficient of variation for different characters of maize

Sr No.	Genotypes	Grain yield per plant (g)	Cob height (cm)	Cob length (cm)	Number of grains per row	Number of rows per cob	100 kernel weight(g)
1.	P1	54.79	121.00	18.67	28.33	15.33	10.70
2.	P2	68.10	96.67	16.00	29.33	13.33	16.07
3.	P3	93.40	66.67	17.00	31.67	15.33	18.60
4.	P4	134.57	115.67	17.33	39.00	14.67	21.15
5.	P5	72.86	112.67	19.33	39.33	15.33	11.60
6.	P6	124.65	116.33	18.67	40.00	14.67	18.63
7.	P7	71.23	101.00	16.33	29.33	14.67	15.40
8.	P8	124.90	95.67	17.33	33.33	14.67	24.60
9.	P9	73.71	100.33	14.67	26.00	12.67	19.80
10.	P10	74.42	101.00	15.67	27.00	14.00	19.24
11.	P1 X P2	68.53	114.33	21.00	28.67	14.00	15.90
12.	P1 X P3	54.87	100.00	17.33	29.33	16.67	9.90
13.	P1 X P4	58.53	106.33	20.00	27.67	16.00	12.60
14.	P1 X P5	63.34	106.00	17.67	28.00	18.00	11.63
15.	P1 X P6	58.57	105.00	15.33	27.33	14.67	13.20
16.	P1 X P7	86.38	89.00	18.67	28.00	16.00	19.27
17.	P1 X P8	48.54	87.00	15.00	26.67	16.00	10.00
18.	P1 X P9	78.12	86.00	17.33	29.33	13.33	17.37
19.	P1 X P10	66.83	79.67	17.67	27.67	16.67	13.46
20.	P2 X P3	52.07	86.00	15.67	30.67	13.33	10.73
21.	P2 X P4	36.46	99.00	12.67	17.00	14.00	12.73
22.	P2 X P5	61.91	82.33	13.33	29.33	14.00	13.07
23.	P2 X P6	87.13	86.33	18.00	30.33	13.33	18.50
24.	P2 X P7	77.65	79.00	18.00	32.67	15.33	14.20
25.	P2 X P8	67.24	80.67	15.67	31.67	13.67	14.10
26.	P2 X P9	29.99	96.00	13.00	17.00	12.00	13.73
27.	P2 X P10	71.00	83.33	15.33	26.67	14.67	16.53
28.	P3 X P4	81.96	93.67	17.33	33.00	14.00	16.00
29.	P3 X P5	78.79	92.00	17.00	33.00	14.00	15.93
30.	P3 X P6	45.19	95.67	15.67	32.33	13.33	9.26
31.	P3 X P7	38.28	79.33	16.67	30.00	10.67	10.67
32.	P3 X P8	125.78	105.33	17.33	33.67	13.33	26.20
33.	P3 X P9	148.49	99.00	19.67	39.33	13.33	26.60
34.	P3 X P10	182.18	113.33	19.00	41.33	17.33	23.37
35.	P4 X P5	80.53	115.67	16.33	30.00	16.00	14.90
36.	P4 X P6	86.17	119.33	19.33	31.00	13.33	20.07
37.	P4 X P7	93.01	107.33	21.00	41.00	13.33	16.20
38.	P4 X P8	95.67	119.67	16.67	36.00	15.33	15.33
39.	P4 X P9	65.62	125.00	15.00	28.33	14.67	14.47
40.	P4 X P10	73.88	105.67	15.67	27.67	16.67	14.63
41.	P5 X P6	51.10	122.33	15.33	30.33	11.33	13.56
42.	P5 X P7	136.29	105.33	18.33	34.33	15.33	25.58
43.	P5 X P8	102.72	116.00	17.00	37.33	15.33	16.70
44.	P5 X P9	158.05	119.33	20.00	40.33	18.00	21.10
45.	P5 X P10	140.61	116.67	18.33	34.33	16.00	23.27
46.	P6 X P7	67.31	130.67	18.00	30.00	15.33	13.47

47.	P6 X P8	111.13	134.67	20.00	33.00	14.67	19.65
48.	P6 X P9	109.98	117.00	19.33	36.33	14.67	20.37
49.	P6 X P10	80.85	120.33	16.67	30.33	16.00	15.47
50.	P7 X P8	73.08	113.67	18.00	29.00	15.33	15.23
51.	P7 X P9	71.58	105.33	19.00	30.00	14.67	15.50
52.	P7 X P10	67.40	96.00	20.00	30.00	14.00	15.20
53.	P8 X P9	79.94	106.00	17.33	32.67	14.67	16.77
54.	P8 X P10	77.87	104.33	14.67	33.00	13.33	16.53
55.	P9 X P10	63.52	107.33	19.33	26.00	13.33	17.27
56.	GAYMH1	83.08	113.33	16.67	29.33	15.33	16.50
57.	HQPM 1	37.56	113.33	14.67	29.00	13.33	12.47
Mean		81.88	103.61	17.23	31.11	14.60	16.33
S. Em.±		7.20	7.40	0.81	2.00	0.88	0.92
Range		29.99 - 182.18	66.67 - 134.67	12.67 - 21.00	17.00 - 41.33	10.67 - 18.00	9.26 - 26.60
C.D. (5%)		20.17	20.74	2.27	5.60	2.46	2.56
C.V. (%)		15.22	12.37	8.16	11.12	10.43	9.71
Broad sense heritability (%)		92.75	70.14	78.23	79.05	60.89	93.19

Table 2 Genotypic and phenotypic correlation coefficients between different characters in maize.

Character		GY	CH	CL	NOGPR	NORC	100KW
GY	rg	1.0000	0.3404**	0.5594**	0.7795**	0.4055**	0.8929**
	rp	1.0000	0.1898	0.4092**	0.7222**	0.3215*	0.7891**
CH	rg	-	1.0000	0.4292**	0.3238*	0.3557**	0.1908
	rp	-	1.0000	0.1531	0.1961	0.0773	0.1186
CL	rg	-	-	1.0000	0.6871**	0.3437**	0.4089**
	rp	-	-	1.0000	0.3988**	0.2348	0.2783*
NOGPR	rg	-	-	-	1.0000	0.2714	0.5032**
	rp	-	-	-	1.0000	0.1368	0.3841**
NORC	rg	-	-	-	-	1.0000	0.0700
	rp	-	-	-	-	1.0000	0.0053
100 KW	rg	-	-	-	-	-	1.0000
	rp	-	-	-	-	-	1.0000

r_g = genotypic correlation r_p = phenotypic correlation
*, ** Significant at P<0.05 and <0.01 level, respectively
Where, GY: Grain yield per plant, CH: Cob height, CL: Cob length, NOGPR: Number of grains per row, NORC: Number of rows per cob, 100 KW: 100 kernel weight

weight was also found highly significant and positive at genotypic and phenotypic level.

Positive and significant genotypic and phenotypic correlation between grain yield and cob height was observed by Hussain *et al.* (2016), Prasad and Shivani (2017). Similarly positive and significant genotypic and phenotypic association of grain yield with number of grains per row, number of rows per cob and 100 kernel weight were observed by Bocanski *et al.* (2009), Rani et al. (2017), Prasad and Shivani (2017), Bisen *et al.* (2018) and Varalakshmi *et al.* (2018) in maize.

Selection indices using different weights

Selection indices were worked out taking six biometrical characters and were constructed taking all possible combinations of the characters. Total 63 selection indices were constructed using equal weight (W1), genotypic correlation coefficients (W2) and phenotypic correlation coefficients (W3) for all characters. The expected genetic gain and percent relative efficiency (PRE) of different indices were worked out and the results are given in Table 3 to 8.

Table 3 Selection indices, expected genetic gain and per cent relative efficiency (PRE) for single character by using differential weight methods

Sr. No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_1	I=0.86X1	59.09	100.00
I_2	I=0.492X2	18.22	30.83
I_3	I=0.612X3	2.84	4.82
I_4	I=0.625X4	7.27	12.31
I_5	I=0.371X5	1.46	2.48
I_6	I=0.869X6	7.82	13.24
2	Genotypic correlation taken as weight (W2)		
I_1	I=0.86X1	59.09	100.00
I_2	I=0.167X2	6.20	10.50
I_3	I=0.342X3	1.59	2.69
I_4	I=0.487x4	5.66	9.59
I_5	I=0.15X5	0.59	1.01
I_6	I=0.775X6	6.98	11.82
3	Phenotypic correlation taken as weight (W3)		
I_1	I=0.86X1	59.09	100.00
I_2	I=0.093X2	3.45	5.85
I_3	I=0.25X3	1.16	1.97
I_4	I=0.451x4	5.25	8.89
I_5	I=0.119X5	0.47	0.80
I_6	I=0.685X6	6.17	10.45

Table 4 Selection indices, expected genetic gain and per cent relative efficiency (PRE) for possible combinations of two characters by using differential weight methods

Sr. No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_{12}	I=0.92X1+0.579X2	70.51	119.32
I_{13}	I=0.846X1+1.493X3	61.31	103.75
I_{14}	I=0.978X1-0.171X4	65.76	111.28
I_{15}	I=0.884X1-0.59X5	60.04	101.60
I_{16}	I=0.696X1+2.567X6	67.55	114.32
I_{23}	I=0.485X2+1.897X3	21.19	35.86
I_{24}	I=0.494X2+0.888X4	22.70	38.41
I_{25}	I=0.496X2+1.434X5	19.65	33.26
I_{26}	I=0.489X2+1.143X6	21.87	37.02
I_{34}	I=1.049X3+0.628X4	10.27	17.39
I_{35}	I=0.676X3+0.377X5	3.78	6.40
I_{36}	I=0.692X3+0.923X6	9.71	16.44
I_{45}	I=0.646X4+0.495X5	8.02	13.59
I_{46}	I=0.6X4+1.05X6	13.74	23.25
I_{56}	I=0.45X5+0.885X6	8.17	13.84
2	Genotypic correlation taken as weight (W2)		
I_{12}	I=0.873X1+0.271X2	62.66	106.04
I_{13}	I=0.841X1+1.257X3	60.38	102.19
I_{14}	I=0.969X1-0.269X4	64.31	108.84
I_{15}	I=0.88X1-0.787X5	59.53	100.75
I_{16}	I=0.693X1+2.493X6	66.74	112.94

I_{23}	I=0.169X2+0.775X3	7.69	13.01
I_{24}	I=0.176X2+0.572X4	10.19	17.25
I_{25}	I=0.17X2+0.512X5	6.75	11.43
I_{26}	I=0.17X2+0.867X6	10.58	17.92
I_{34}	I=0.702X3+0.47X4	7.40	12.53
I_{35}	I=0.368X3+0.157X5	1.95	3.30
I_{36}	I=0.427X3+0.8X6	7.99	13.52
I_{45}	I=0.493X4+0.251X5	5.96	10.09
I_{46}	I=0.471X4+0.915X6	11.52	19.50
I_{56}	I=0.222X5+0.782X6	7.10	12.02
3	Phenotypic correlation taken as weight (W3)		
I_{12}	I=0.862X1+0.2X2	61.08	103.37
I_{13}	I=0.839X1+1.177X3	60.07	101.66
I_{14}	I=0.966X1-0.294X4	63.94	108.20
I_{15}	I=0.88X1-0.815X5	59.46	100.63
I_{16}	I=0.69X1+2.422X6	65.95	111.61
I_{23}	I=0.096X2+0.489X3	4.50	7.63
I_{24}	I=0.104X2+0.495X4	7.52	12.73
I_{25}	I=0.096X2+0.32X5	3.86	6.54
I_{26}	I=0.096X2+0.736X6	7.88	13.34
I_{34}	I=0.593X3+0.426X4	6.56	11.12
I_{35}	I=0.271X3+0.123X5	1.45	2.46
I_{36}	I=0.328X3+0.701X6	6.89	11.67
I_{45}	I=0.456X4+0.213X5	5.48	9.28
I_{46}	I=0.435X4+0.815X6	10.40	17.60
I_{56}	I=0.182X5+0.69X6	6.26	10.60

Table 5 Selection indices, expected genetic gain and relative efficiency (%) for possible combination of three characters by using different weight methods

Sr. No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_{123}	I=0.88X1+0.575X2+2.464X3	73.28	124.01
I_{124}	I=1.048X1+0.607X2-0.279X4	77.15	130.56
I_{125}	I=0.93X1+0.59X2+0.152X5	71.51	121.01
I_{126}	I=0.791X1+0.591X2+2.222X6	78.09	132.14
I_{134}	I=0.955X1+2.144X3-0.246X4	68.23	115.46
I_{135}	I=0.87X1+1.646X3-0.77X5	62.31	105.44
I_{136}	I=0.668X1+1.726X3+2.642X6	69.75	118.03
I_{145}	I=1.017X1-0.253X4-0.844X5	66.74	112.94
I_{146}	I=0.771X1+0.267X4+2.462X6	73.82	124.92
I_{156}	I=0.703X1+0.484X5+2.543X6	68.28	115.54
I_{234}	I=0.491X2+2.253X3+0.7X4	26.31	44.53
I_{235}	I=0.494X2+1.799X3+1.132X5	22.39	37.90
I_{236}	I=0.485X2+1.922X3+1.022X6	24.94	42.21
I_{245}	I=0.499X2+0.861X4+1.47X5	24.11	40.81
I_{246}	I=0.493X2+0.814X4+1.216X6	27.18	45.99
I_{256}	I=0.493X2+1.513X5+1.155X6	23.23	39.31
I_{345}	I=1.092X3+0.647X4+0.386X5	11.05	18.70
I_{346}	I=1.093X3+0.596X4+1.049X6	16.38	27.72
I_{356}	I=0.738X3+0.439X5+0.933X6	10.21	17.29
I_{456}	I=0.614X4+0.586X5+1.059X6	14.30	24.20

2	Genotypic correlation taken as weight (W2)		
I_{123}	I=0.846X1+0.267X2+1.536X3	64.10	108.48
I_{124}	I=0.988X1+0.295X2-0.34X4	67.94	114.98
I_{125}	I=0.888X1+0.277X2-0.547X5	63.09	106.76
I_{126}	I=0.713X1+0.285X2+2.404X6	70.05	118.54
I_{134}	I=0.945X1+1.818X3-0.364X4	65.80	111.34
I_{135}	I=0.86X1+1.386X3-0.951X5	60.86	103.00
I_{136}	I=0.659X1+1.486X3+2.567X6	68.05	115.15
I_{145}	I=1.003X1-0.349X4-1.032X5	64.80	109.65
I_{146}	I=0.756X1+0.181X4+2.394X6	71.61	121.19
I_{156}	I=0.689X1+0.331X5+2.523X6	67.03	113.44
I_{234}	I=0.177X2+1.105X3+0.49X4	12.25	20.73
I_{235}	I=0.173X2+0.745X3+0.412X5	8.16	13.82
I_{236}	I=0.171X2+0.84X3+0.832X6	12.10	20.49
I_{245}	I=0.179X2+0.561X4+0.579X5	10.72	18.15
I_{246}	I=0.177X2+0.539X4+0.969X6	15.18	25.70
I_{256}	I=0.171X2+0.581X5+0.872X6	11.02	18.65
I_{345}	I=0.717X3+0.478X4+0.167X5	7.70	13.04
I_{346}	I=0.751X3+0.45X4+0.904X6	13.00	22.00
I_{356}	I=0.439X3+0.208X5+0.805X6	8.15	13.80
I_{456}	I=0.472X4+0.33X5+0.921X6	11.73	19.86
3	Phenotypic correlation taken as weight (W3)		
I_{123}	I=0.838X1+0.196X2+1.298X3	62.13	105.15
I_{124}	I=0.974X1+0.224X2-0.357X4	65.99	111.67
I_{125}	I=0.879X1+0.206X2-0.69X5	61.45	103.98
I_{126}	I=0.693X1+0.215X2+2.391X6	67.82	114.77
I_{134}	I=0.942X1+1.715X3-0.397X4	65.10	110.16
I_{135}	I=0.858X1+1.302X3-0.974X5	60.48	102.35
I_{136}	I=0.654X1+1.403X3+2.495X6	66.96	113.31
I_{145}	I=1X1-0.374X4-1.058X5	64.35	108.90
I_{146}	I=0.748X1+0.168X4+2.33X6	70.47	119.26
I_{156}	I=0.684X1+0.32X5+2.462X6	66.19	112.01
I_{234}	I=0.104X2+0.814X3+0.435X4	9.06	15.33
I_{235}	I=0.099X2+0.477X3+0.264X5	4.87	8.25
I_{236}	I=0.098X2+0.556X3+0.718X6	8.91	15.08
I_{245}	I=0.106X2+0.49X4+0.393X5	7.90	13.37
I_{246}	I=0.105X2+0.47X4+0.844X6	12.25	20.73
I_{256}	I=0.098X2+0.381X5+0.74X6	8.15	13.80
I_{345}	I=0.605X3+0.432X4+0.135X5	6.80	11.51
I_{346}	I=0.636X3+0.408X4+0.8X6	11.51	19.49
I_{356}	I=0.337X3+0.168X5+0.705X6	7.02	11.88
I_{456}	I=0.435X4+0.283X5+0.82X6	10.57	17.90

Expected genetic gain and relative efficiency (%) for single character

The selection indices were constructed for single character separately. Total six selection indices were constructed for each weight methods (W1, W2 and W3). The selection indices with their expected genetic advance and per cent relative efficiency are presented in Table 3. The genetic gain in maize grain yield per plant (59.09) with equal weight was considered as a base in all single as well as combinations of characters. Relative to this, the efficiency was worked out for selection of single character for different methods. Per cent relative efficiency (PRE) for selection index of biometrical characters ranged from 2.48 to 100, 1.01 to 100.00, 0.80 to 100.00 for W1, W2 and W3 respectively. The highest PRE were observed for grain yield per plant in equal weight methods. The lowest PRE were

Table 6 Selection indices, expected genetic gain and per cent relative efficiency (PRE) for possible combinations of four characters by using differential weight methods

Sr. No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_{1234}	I=1.009X1+0.6X2+3.157X3-0.438X4	80.24	135.79
I_{1235}	I=0.893X1+0.586X2+2.543X3-0.148X5	74.30	125.74
I_{1236}	I=0.731X1+0.586X2+2.659X3+2.352X6	80.85	136.81
I_{1245}	I=1.067X1+0.62X2-0.317X4-0.126X5	78.15	132.25
I_{1246}	**I=0.912X1+0.612X2+0.006X4+1.958X6**	**84.45**	**142.91**
I_{1256}	I=0.765X1+0.602X2+1.127X5+2.388X6	79.03	133.73
I_{1345}	I=0.999X1+2.376X3-0.369X4-1.158X5	69.30	117.28
I_{1346}	I=0.738X1+2.225X3+0.205X4+2.528X6	76.25	129.03
I_{1356}	I=0.682X1+1.757X3+0.306X5+2.568X6	70.49	119.29
I_{1456}	I=0.797X1+0.225X4+0.255X5+2.345X6	74.55	126.16
I_{2345}	I=0.5X2+2.154X3+0.703X4+1.131X5	27.49	46.52
I_{2346}	I=0.492X2+2.275X3+0.649X4+1.125X6	30.70	51.96
I_{2356}	I=0.493X2+1.795X3+1.211X5+1.051X6	26.08	44.14
I_{2456}	I=0.498X2+0.772X4+1.582X5+1.248X6	28.50	48.24
I_{3456}	I=1.119X3+0.613X4+0.47X5+1.053X6	16.99	28.76
2	Genotypic correlation taken as weight (W2)		
I_{1234}	I=0.96X1+0.288X2+2.111X3-0.458X4	69.59	117.77
I_{1235}	I=0.862X1+0.272X2+1.64X3-0.744X5	64.56	109.26
I_{1236}	I=0.672X1+0.28X2+1.749X3+2.492X6	71.50	121.00
I_{1245}	I=1.016X1+0.303X2-0.408X4-0.816X5	68.40	115.76
I_{1246}	**I=0.798X1+0.3X2+0.059X4+2.233X6**	**74.99**	**126.90**
I_{1256}	I=0.698X1+0.289X2+0.555X5+2.5X6	70.39	119.11
I_{1345}	I=0.984X1+2.023X3-0.481X4-1.324X5	66.36	112.29
I_{1346}	I=0.726X1+1.892X3+0.092X4+2.436X6	73.08	123.67
I_{1356}	I=0.663X1+1.496X3+0.171X5+2.55X6	68.34	115.65
I_{1456}	I=0.763X1+0.173X4+0.151X5+2.366X6	71.91	121.69
I_{2345}	I=0.18X2+1.073X3+0.492X4+0.417X5	12.69	21.47
I_{2346}	I=0.178X2+1.146X3+0.463X4+0.928X6	17.05	28.86
I_{2356}	I=0.174X2+0.793X3+0.468X5+0.843X6	12.49	21.14
I_{2456}	I=0.179X2+0.521X4+0.664X5+0.983X6	15.63	26.45
I_{3456}	I=0.752X3+0.456X4+0.236X5+0.907X6	13.22	22.39
3	Phenotypic correlation taken as weight (W3)		
I_{1234}	I=0.948X1+0.217X2+1.844X3-0.468X4	67.22	113.76
I_{1235}	I=0.855X1+0.2X2+1.409X3-0.862X5	62.53	105.81
I_{1236}	I=0.655X1+0.209X2+1.512X3+2.469X6	68.89	116.58
I_{1245}	I=1.004X1+0.231X2-0.433X4-0.956X5	66.39	112.36
I_{1246}	**I=0.767X1+0.229X2+0.078X4+2.247X6**	**72.39**	**122.50**
I_{1256}	I=0.681X1+0.219X2+0.448X5+2.469X6	68.08	115.21
I_{1345}	I=0.98X1+1.916X3-0.513X4-1.343X5	65.58	110.99
I_{1346}	I=0.719X1+1.782X3+0.069X4+2.364X6	71.62	121.20
I_{1356}	I=0.656X1+1.408X3+0.165X5+2.49X6	67.19	113.71
I_{1456}	I=0.75X1+0.169X4+0.161X5+2.325X6	70.71	119.66
I_{2345}	I=0.107X2+0.799X3+0.437X4+0.272X5	9.38	15.87
I_{2346}	I=0.105X2+0.852X3+0.413X4+0.813X6	13.58	23.00
I_{2356}	I=0.101X2+0.531X3+0.311X5+0.725X6	9.16	15.51
I_{2456}	I=0.107X2+0.459X4+0.466X5+0.854X6	12.55	21.24
I_{3456}	I=0.635X3+0.412X4+0.196X5+0.803X6	11.69	19.79

Table 7 Selection indices, expected genetic gain and per cent relative efficiency (PRE) for possible combinations of five characters by using differential weight methods

Sr.No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_{12345}	I=1.038X1+0.613X2+3.308X3-0.521X4-0.594X5	81.31	137.59
I_{12346}	**I=0.861X1+0.604X2+3.23X3-0.138X4+2.031X6**	**87.48**	**148.04**
I_{12356}	I=0.72X1+0.597X2+2.642X3+0.843X5+2.435X6	81.77	138.37
I_{12456}	I=0.895X1+0.622X2+0.054X4+0.751X5+2.045X6	85.35	144.44
I_{13456}	I=0.793X1+2.318X3+0.084X4-0.112X5+2.26X6	77.01	130.33
I_{23456}	I=0.5X2+2.148X3+0.642X4+1.233X5+1.158X6	31.82	53.85
2	Genotypic correlation taken as weight (W2)		
I_{12345}	I=0.994X1+0.296X2+2.289X3-0.564X4-1.149X5	70.13	118.67
I_{12346}	**I=0.763X1+0.293X2+2.181X3-0.051X4+2.276X6**	**76.62**	**129.65**
I_{12356}	I=0.666X1+0.284X2+1.74X3+0.365X5+2.532X6	71.83	121.56
I_{12456}	I=0.792X1+0.305X2+0.076X4+0.291X5+2.263X6	75.32	127.46
I_{13456}	I=0.761X1+1.95X3+0.011X4-0.205X5+2.262X6	73.39	124.19
I_{23456}	I=0.181X2+1.096X3+0.461X4+0.492X5+0.941X6	17.43	29.49
3	Phenotypic correlation taken as weight (W3)		
I_{12345}	I=0.984X1+0.223X2+2.03X3-0.58X4-1.258X5	67.70	114.56
I_{12346}	**I=0.736X1+0.221X2+1.908X3-0.028X4+2.281X6**	**73.61**	**124.56**
I_{12356}	I=0.651X1+0.213X2+1.506X3+0.281X5+2.498X6	69.15	117.01
I_{12456}	I=0.764X1+0.232X2+0.089X4+0.219X5+2.266X6	72.64	122.93
I_{13456}	I=0.75X1+1.832X3-0.001X4-0.193X5+2.213X6	71.86	121.61
I_{23456}	I=0.108X2+0.823X3+0.412X4+0.336X5+0.821X6	13.85	23.44

Table 8 Selection indices, expected genetic gain and per cent relative efficiency (PRE) for possible combinations of six characters by using differential weight methods

Sr. No.	Equations	Genetic Gain	PRE
1	Equal weight (W1)		
I_{123456}	I=0.893X1+0.615X2+3.282X3+0.207X4+0.163X5+1.877X6	88.39	149.59
2	Simple correlation coefficients taken as weight (W2)		
I_{123456}	I=0.764X1+0.225X2+1.947X3-0.093X4-0.162X5+2.144X6	73.85	124.97
3	Genotypic correlation taken as weight (W3)		
I_{123456}	I=0.791X1+0.298X2+2.226X3-0.118X4-0.127X5+2.135X6	76.95	130.23

observed for number of rows per cob in all weight methods. Among the different characters under study, the highest per cent relative efficiency was observed (100) for grain yield per plant by all the methods. Grain yield per plant had equal PRE (100) in, equal weight, genotypic correlation coefficients and phenotypic correlation coefficients taken as weight because their weights were the same. In general the percent relative efficiency was higher in equal weight method as compared to other methods. This result in accordance with Al-Obaidy *et al.* (2015) in maize. Habib *et al.* (2007), Akter*et al.* (2010), Anuradha & Rao (2015) and Chaudhary *et al.* (2017) also found the similar result in rice

Expected genetic gain and relative efficiency (%) for combination of two characters

All possible combinations of two characters were used to construct selection indices using different weights (W1 to W3). Total 15 selection indices in each weight method were constructed and the indices with their per cent relative efficiency are given in Table 4.

The genetic gain for grain yield (single character) with equal weight method (59.0959) was considered as base and the efficiency was worked out for all

Table 9 Top three ranking selection indices in different weight methods with maize grain yield per plant

Combinations	Top Rank	Equal Wt.[W1]	GC Wt. [W2]	PC Wt. [W3]
Combinations of two characters	1	I_{12} (119.32)	I_{16} (112.94)	I_{16} (111.61)
	2	I_{16} (114.32)	I_{14} (108.84)	I_{14} (108.20)
	3	I_{14} (111.28)	I_{12} (106.04)	I_{12} (103.37)
Combinations of three characters	1	I_{126} (132.14)	I_{146} (121.19)	I_{146} (119.26)
	2	I_{124} (130.56)	I_{126} (118.54)	I_{126} (114.77)
	3	I_{146} (124.92)	I_{136} (115.15)	I_{136} (113.31)
Combinations of four characters	1	I_{1246} (142.91)	I_{1246} (126.90)	I_{1246} (122.50)
	2	I_{1236} (136.81)	I_{1346} (123.67)	I_{1346} (121.20)
	3	I_{1234} (135.79)	I_{1456} (121.69)	I_{1456} (119.66)
Combinations of five characters	1	I_{12346} (148.04)	I_{12346} (129.65)	I_{12346} (124.56)
	2	I_{12456} (144.44)	I_{12456} (127.46)	I_{12456} (122.93)
	3	I_{12356} (138.37)	I_{13456} (124.19)	I_{13456} (121.61)

Table 10 Rank correlations between different weight methods based on best selection index of respective weight methods including maize grain yield per plant

Weight	Equal wt.	GC Wt.	PC Wt.
Equal Wt.	1.0000**	0.9793**	0.9713**
GCWt.	0.9793**	1.0000**	0.9983**
PCWt.	0.9713**	0.9983**	1.0000**

selection indices of all possible combinations of six characters for different weights. PRE ranged between 6.40 (cob length and number of rows per cob) to 119.32 (Grain yield and cob height) for equal weight method, 3.30 (cob length and number of rows per cob) to 112.94 (grain yield and 100 kernel weight) for genotypic correlation weight method and 2.46 (cob length and number of rows per cob) to 111.61 (grain yield and 100 kernel weight) for phenotypic correlation weight method.

Expected genetic gain and relative efficiency (%) for combination of three characters

Out of six (biometrical characters) characters all possible combinations of three characters were taken at a time to construct selection indices using different weights. Total 20 indices consisting different combinations of characters were constructed. Different indices with their genetic gain and per cent relative efficiency for different weight method are given in Table 5.

The genetic gain for grain yield per plant (59.09) alone with equal weight method was used as base to workout per cent relative efficiency for all selection indices. Per cent relative efficiency ranged from

17.29 (cob length, number of rows per cob and 100 kernel weight) to 132.14 (Grain yield per plant, cob height and 100 kernel weight) for equal weight, 13.04 (cob length, number of grains per row and number of rows per cob) to 121.19 (grain yield per plant, number of grains per row and number of rows per cob) for genotypic correlation weight, 8.25 (cob height, cob length and number of rows per cob) to 119.26 (grain yield per plant, number of grains per row and 100 kernel weight) for phenotypic correlation.

Expected genetic gain and relative efficiency (%) for combination of four characters

There were fifteen different possible combinations of four characters and were used to selection indices with different weights. Selection indices, their genetic gain and their percent relative efficiency are given in Table 6.

The results revealed that PRE ranged from 28.76 (I3456) [cob length, number of grains per row, number of rows per cob and 100 kernel weight] to 142.91 (I1246) [Grain yield per plant, cob height, number of rows per cob and 100 kernel weight] for equal weight, 21.14 (I2356) [cob height, cob length, number of rows per cob and 100 kernel weight] to 126.90 (I1246) [Grain yield per plant, cob height, number of rows per cob and 100 kernel weight] for simple correlation, 15.51 (I2356) [cob height, cob length, number of rows per cob and 100 kernel weight] to 122.50 (I1246) [Grain yield per plant, cob height, number of rows per cob and 100 kernel weight] for phenotypic correlation.

It was reported that the higher per cent relative efficiency was observed in equal method as compared to the rest of the weight methods as the numerical value of weight was higher as compared to all methods. Index (I1246) gave highest PRE in equal weight (142.91), genotypic correlation as weight (126.90) and phenotypic correlation as weight gave (122.50).

Expected genetic gain and relative efficiency (%) for five characters

Out of six characters all possible combinations of five different characters were taken at a time to construct selection indices using different weight methods. Six different indices were constructed for each weight methods so total 18 indices were constructed using this method. Different indices with their genetic gain and per cent relative efficiency for different weight method are presented in Table 7. The genetic gain for grain yield per plant (59.09) alone with equal weight method was used as base to workout per cent relative efficiency for all the selection indices.

Per cent relative efficiency ranged from 53.85 (I23456) [cob height, cob length, number of grains per row, number of rows per cob, 100 kernel weight] to 148.04 (I12346) [Grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight] for equal weight,29.49 (I23456) [Grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight] to 129.65 (I12346) [Grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight] for genotypic correlation, 23.44 (I23456) [Grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight] to 124.56 (I12346) [Grain yield per plant, cob height, cob length, number of grains per row and 100 kernel weight] for phenotypic correlation

Expected genetic gain and relative efficiency (%) for six characters

Combinations of all six biometrical characters were used to construct selection indices using different weights. The selection indices with their per cent relative efficiency are presented in Table 8. The genetic gain for grain yield alone (59.09) with equal weight was considered as 100 PRE. Per cent relative efficiencies were 149.59, 130.23 and 125.00 to equal weight, genotypic correlation and phenotypic correlation, respectively.

Comparison of three ranking selection indices

The results presented in Table 9 showed that the selection index (I_{12346}), which was combination of grain yield per plant, cob height, cob length, number of grains per rows and 100 kernel weight possessed highest PRE for all the weight method. Thus, based on this results taking of equal weight method the per cent relative efficiency was highest and one can use equal weight (W_1) of characters for construction of selection indices to achieve higher genetic gain followed by genotypic correlation (W2) and phenotypic correlation (W3).

Selection score with rank for twenty one genotypes based on different indices

The index score values were worked out for all three weight methods in all genotypes with respect to highest PRE given by different combination of characters. The results indicated that in general PRE with equal weight was higher than rest of the weights in all combinations of indices. The rank correlation among different methods for selection score values (Table 10) were positive and highly significant indicating agreement with all methods.

CONCLUSION

The selection index (I_{12346}), which was combination of grain yield per plant, cob height, cob length, number of grains per rows and 100 kernel weight possessed highest PRE for all weight methods. Thus, based on this results taking of equal weight method, the per cent relative efficiency was highest and one can use equal weight (W_1) of characters for construction of selection indices to achieve higher genetic gain followed by genotypic correlation (W2) and phenotypic correlation (W3).

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A study on performance of Mudra Yojana in India

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ABSTRACT

Micro Units Development & Refinance Agency Limited (MUDRA) was embarked on 8th April 2015 by Shri Narendra Modi, the Hon'ble Prime Minister to ensure that manufacturing, trading, processing and services sector activities are securely financed. In the developing countries small business gain a beneficial role in contributing towards GDP of the country. In India, MUDRA is playing a pivotal role in development and refinancing activities of the smaller units. Small business activities plays a major role in providing employment for large number of population. Till 2019, nearly 1477 lakh accounts are opened under the MUDRA yojana of which the major share is of Shishu, Kishore and at last Tarun category. The paper attempts to know the growth and performance of different category of accounts which fall under MUDRA for the benefit of the population since from the inception of the scheme

Keywords: MUDRA, Growth rate, Instability Index, Correlation, Category.

Finance is one of the factors occupying an important place in all types of economic activities. It helps in greasing the wheels of industrial progress of any country. The growth of any industry largely depends on the availability of adequate finance in proper time. In the process of development, the non availability of timely and adequate finance generally acts as a severe restraining factor. Finance being the lifeblood of business and industry, a sound financial system is a pre-requisite for planned economic development in a developing economy. The general financial weaknesses, which characterize the small scale sector, are their inadequate financial resources, low capital outlay, inability to offer acceptable security and absence of properly maintained accounts. All these are responsible for the failure of several units. Very often, shortage of finance is in most cases a symptom of other problems such as poor planning, outmoded technology, ineffective market, bad product design and lack of cost accounting and so on. Finance therefore, assumes a very great importance in the development of small scale industry. Financial Inclusion is one of the most treasured strategies in India. Our monetary arrangement has dependably been driven by a basic plan of a practical and comprehensive development. The concept of financial inclusion was first introduced by the then Governor of RBI, Shri Y.V. Reddy in 2005. Financial Inclusion means process of ensuring access to appropriate financial services to all the sections of society such as low income groups and weaker section at an affordable rate. Government of India has introduced a number of financial inclusion initiatives such as Pradhan Mantri Mudra Yojana (PMMY),

The MUDRA loans are extended under three categories, namely, MUDRA Shishu (Startups) Loans upto Rs 50,000/- with interest at around 10 to 12 per cent; MUDRA Kishore (existing units that lack exposure) Loans from Rs 50,001 to Rs 5 lakh at interest rate between 14 to 17 per cent and MUDRA Tarun (Units that have grown to certain level and have exposure, but need support to reach higher level) Loans from Rs 5,00,001/- to Rs 10 lakh at interest rate starting from 16 per cent, which varies from bank to bank. Eligible barrowers of MUDRA loan include all individuals, proprietary concerns, partnership firm, private Ltd. companies, public companies and other legal forms. MUDRA loans can be obtained from financial institutes like commercial banks, RRBs, cooperative banks etc listed under the scheme as the loan providers. The scheme focuses

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only on small scale units and not on the large ones.

MATERIALS AND METHODS

The data used for the study is entirely based on secondary source of data which was obtained for the period of 2015 to 2019 from the source of Indiastat. In order to arrive at the meaningful results following statistical tools were employed for the study

a) Growth rate
b) Coefficient of Variation
c) Percentage analysis

RESULTS AND DISCUSSION

With the inception of the MUDRA Yojana in India, growth rate of the accounts opened and amount disbursed was calculated for the year 2016 to 2019 which is depicted in Table no 1. It can be observed from the table that there is a positive growth rate of accounts opened and amount disbursed for all the category of accounts of MUDRA. Highest growth rate in accounts opened was observed for the Tarun category which was 81.10 per cent, with the support of time variable of 96.83. It was followed by Kishore category accounts which was 57.47 per cent of growth while time variable explaining to the tune of 98.29. As compared with the Tarun and Kishore category the demand for Shishu category was not much as it can be observed growth rate was slow with 18.71 per cent while time variable supported to the extent of 99.71. For the amount that was disbursed by the financial institutions for the study period, highest growth rate was observed for the Kishore category with the value of 39.62 per cent and time variable explaining to the tune of 93.80. The next category which showed the highest growth rate after Kishore category was Tarun category which was at 33.81 per cent for which the time variable support was around 97.31. As like growth rate of accounts opened, the least was found to be with the Shishu category with 29.33 percent supported with the time variable of 99.29. Instability Index was high in case of Tarun category followed by Kishore category and Shishu category under the accounts opened, while in amount disbursed high was observed for Kishore category followed by Tarun and Shishu category.

Table 2 presents percentage share of accounts opened and loan disbursed under different category of accounts. In case of category shishu the accounts opened among total is gradually decreasing, in the year 2016-17 accounts opened was 364.98 lakh's with the share of 91.93 per cent, 2017-18 it was 426.69 lakh's having the share of 88.65 per cent and in the year 2018-19 it was around 515.07 lakh's with the percentage of 86.03. Of the amount disbursed of total accounts the share was decreased for the second year as indicated in the table. In the year 2016-17 Rs 85,100.74 crore's was disbursed having the share of 47.13 per cent, In the year 2017-18, amount disbursed under Shishu category was Rs 1,06,001.60 crore's with the share of 41.78 per cent for the financial year. For the year 2018-19 the share was considerably increased which was around 44.24 per cent with the disbursed amount to be Rs 1,42,345.25 crores.

In case of Kishore category of MUDRA accounts, share of the accounts opened to the total accounts gradually increased year by year. In the year 2016-17 accounts which were opened are 26.64 lakhs with the share of 6.71 per cent, in the year 2017-18 accounts were around 46.53 lakhs under the category having the share of 9.66 per cent. For the year 2019-20, share was around 11.03 per cent with the accounts opened at 66.06 lakhs. Of the amount disbursed in the year 2016-17 the share was around 29.66 per cent of the total with the amount of Rs 53,545.14 crores. In the year 2017-18 the share was around 34.19 per cent of the total with the amount disbursement of Rs 86,732.16 crores. At last in the year 2018-19 the share of the total was decreased even though the actual amount increased when compared to previous year which was around Rs 1,04,386.68 crore's having the percentage of 32.44 per cent of the total.

The share of Tarun category accounts opened for the year 2016-17 was 1.35 per cent with 5.36 lakh accounts. In the year 2017-18, share was 1.67 per cent of the total and athe accounts which were opened are 8.06 lakhs and in 2018-19 accounts opened were 17.58 lakhs with the share of 2.93 per cent. While in case of amount disbursed was more or less with the share of 23 to 24 per cent for all the three years. In the year 2016-17, the share was 23.20 per cent and the amount that was disbursed was Rs 41,882.66 crore's. For the year 2017-18 share was 24.02 per cent of the total amount disbursed with the amount disbursed of Rs

Table 1 Growth rate of number of accounts opened and amount disbursed from the year 2016-2019 under mudra yojana in India.

	Shishu Category		Kishore Category		Tarun Category	
	Accounts opened	Amount disbursed	Accounts opened	Amount disbursed	Accounts opened	Amount disbursed
Growth Rate	18.71%	29.33%	57.47%	39.62%	81.10%	33.81%
R2	99.71*	99.29*	98.29*	93.80**	96.83*	97.31*
CV	17.33	26.06	42.46	31.65	62.12	28.03

* Significant at 1 percent
** Significant at 5 percent

Table 2 Percentage share of accounts opened and amount disbursed in India (2016- 2019)

(Rs. In Crore)

Category	2016-17		2017-18		2018-19	
	Accounts opened *	Amount disbursed	Accounts opened *	Amount disbursed	Accounts opened *	Amount disbursed
Shishu	364.98	85100.74	426.69	106001.6	515.07	142345.25
	(91.93)	(47.13)	(88.65)	(41.78)	(86.03)	(44.24)
Kishore	26.64	53545.14	46.53	86732.16	66.06	104386.68
	(6.71)	(29.66)	(9.66)	(34.19)	(11.03)	(32.44)
Tarun	5.36	41882.66	8.06	60943.34	17.58	74990.86
	(1.35)	(23.20)	(1.67)	(24.02)	(2.93)	(23.30)

* No in lakhs.

Table 3 Correlation between the accounts opened and amount disbursed in india for the period of 2016-2019

	Accounts Opened	Amount Disbursed
Accounts Opened	1	--
Amount Disbursed	0.99	1

* Significant at 10 per cent

60,943.34 crores. At last in the year 2018-19 the share was 23.20 per cent with the disbursed amount of Rs 74,990.86 crores.

Correlation between the accounts opened and amount disbursed was calculated and same is presented in table 3. It can be observed from the table that there is a positive correlation between the accounts opened and amount disbursed for all the study period which was 0.99 and found to be statistically significant at 10 per cent.

CONCLUSION

MUDRA yojana is great initiative by Government of India which is helping the weaker section, low income group and unfunded population and also will increase the competition. It was observed there was huge demand for the loans that are disbursed under MUDRA. The MUDRA is focused to see that unemployed be a successful entrepreneur. The scheme is well accepted by banking and other financial institutions across the country. Government need to impart the information about the benefits of the MUDRA among the public so that more number of people will rely upon opening with the new ventures.

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A study on the dietary habits and activity pattern of selected middle aged adults in Coimbatore

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ABSTRACT

Next to China, India leads the world with highest number of diabetic subjects, acquiring the distinction of being named, "the diabetes capital of the world". One of the most widely recognized issues identified with way of life today is being overweight. Being overweight leads to heart infections, Diabetes Mellitus, hypertension and so on. Objectives: Middle age adulthood is a period where we need to pay attention towards healthy nutritional diet. Preventive measures through assessing the nutritional status of adults such as anthropometric, dietary survey, food consumption pattern, nutritional awareness, physical activity and alertness about diseases will assist the community from being overweight and thus the occurrence of non communicable diseases. Methods: The zone chosen for the conduct of the study was Coimbatore and based on the number of subjects required, their age profile; willingness to participate in the study; their health condition etc.. a private company which was willing was selected. The subjects chosen were in the age group of over 50 years. The selection was carried out using the purposive sampling technique. Results: The data indicates that the adults are in the border line of non-communicable diseases such as overweight or obesity, cardio vascular disease, Type 2 diabetes and hypertension. Conclusion: This could be rectified through regular practice of consuming a nutritious and appropriate diet in conjunction with a physical exercise routine.

Key words: Diabetes, overweight, nutritional awareness, physical activity, Food consumption

INTRODUCTION

As the age advances, the chances and the frequency of a disease/disorder likewise increases (NIH (National Institutes of Health, 2010). We are besieged with nourishment and wellbeing messages regularly and if we pay heed and follow them, there is a strong possibility that it will result in reduction of health issues. for example, weight, heart ailments, hypertension and diabetes (World Health Organization, 1995).

The majority of the worldwide weight of non transmittable maladies in middle age is essentially among Asians (Bloom, D.E. et.al. 2013). The middle adulthood is the bridge between younger and older adulthood i.e around the third quarter of the average lifespan of human being. (Arnett, J.J., 2001). Hence, middle age adulthood is a period to pay attention towards healthy nutritional diet. Global burden of all non-communicable diseases usually have their peak during this period. Preventive measures through assessing the nutritional status of adults and diet counseling will lend a hand to the community in preventing the occurrence of non communicable diseases.

Considering the issues critical to the wellbeing and way of life of middle adulthood, making recommendations for imparting their eating practices, diet, exercise and mental well being are considered important components of the preventive health strategy for adults.

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OBJECTIVES

1. Elicit information on socio economic status of selected adults.
2. Acquire information on physical activity of the selected adults.
3. Assess the nutritional status of the selected

Adults through anthropometric measurement.

4. Study the dietary Perspective of the Selected Adults and make recommendations.

MATERIALS AND METHOD

The zone chosen for the study was Coimbatore. This was due to the ready availability of the required subjects and their willingness to cooperate and participate in this study. The industry chosen was Private Limited Company. The subjects chosen were in the age group of over 50 years covering both genders and utilizing purposive sampling technique.

A number of ninety two subjects over the age of 50 from different branches and division of the private organization were selected for the study. The subjects worked in different shifts like day and night shift. The hours of work are eight to ten hours. The adults aged above 50 years were shortlisted by the management and the investigator and the same was communicated to each department. According to the scheduled timing, the interview schedule was prepared for each day and thus the target groups (of age above 50 years) were interviewed by the researcher.

Details regarding socio economic status, physical activity pattern and nutritional status of selected Adults were collected with the help of a interview schedule in which the data are updated in the SPSS version 16. The investigator collected the information using direct personal interview and recorded the data given by the respondents.

Nutritional status was assessed by using selected anthropometric measurement indices. In this study, the anthropometric measurements indices collected were height, weight and BMI for all the selected adults. Body mass index has been proposed as simple and valid metric for monitoring fitness/fatness. (Schroeder and Martorell, 1999). BMI was computed for all the subjects from the height and weight measurements using the following equation.

$$BMI = \frac{\text{Weight (in kg)}}{\text{Height (in m}^2\text{)}}$$

In the current investigation stature and weight were estimated according to the convention and BMI was determined and grouped by the proposals given by International Diabetes Federation (2008).

Dietary assessment

Table 1 Socio economic position of the selected adults *(n= 92)*

Variables		No.	%
Age (yrs)	50-52	51	54
	53-55	31	34
	56-58	10	11
Religion	Hindu	78	85
	Christian	14	15
	Muslim	-	-
Level of education	High School	35	38
	Higher secondary school	41	45
	Graduates	13	14
	Post graduates	3	3
Monthly income	Rs.0 - 3000 Below poverty line (BPL)	-	-
	Rs.3000-5000 Low income group (LIG)	-	-
	Rs.5000-10000 Middle income group (MIG)	-	-
	Rs.above 10000 High income group (HIG)	92	100
Marital Status	Married	91	99
	Single/Unmarried	1	1
Type of Family	Nuclear	79	86
	Joint	13	14
Family Members	< 3	2	2
	3-5	46	50
	5-8	31	34
	>8	13	14

The investigator followed the 24 hours dietary recall method. The amount of food consumed was determined using 24-hour food intake which recorded all foods and beverages consumed. From this the raw ingredients consumed were computed and the nutritive values of the foods were calculated. These values were then compared with RDA to assess the nutritional adequacy of the sub sample.

RESULTS AND DISCUSSION

A. Socio economic position of the selected adults
B. Physical Activity of the selected adults
C. Nutritional status of the selected adults
D. Dietary Perspective of the Selected Adults

A. Socio economic position of the selected adults

The socio economic position of the selected Adults reveals that majority were of Hindu religion, were married, had completed higher secondary education & were in the high income and in nuclear family and were living with small family members.

B. Physical activity of the selected adults

Table 2 Physical activity level of the selected adults

Activity	Number	Percentage
Sedentary	56	61
Moderate	36	39
Heavy	-	-
Total	92	100

Table 2 elucidates 61 per cent (56 subjects) had sedentary activity and 39 per cent were engaged in moderate activity. None of the adults did heavy activity. The results depict that the prevalence rate of non communicable diseases like diabetes and hyper tension was higher among sedentary workers than moderate activity workers. Prolonged sedentary life style, obesity, less physical activity and less exercise leads to non communicable diseases.

C. Nutritional status of the selected adults

I. Anthropometric details

1. Mean height, Weight and BMI

Table 3 Mean height, weight and BMI of the selected adults

Parameters	Mean±S.D (n=92)
Height (cm)	162±9.21
Weight (kg)	68±9.10
BMI (kg/m2)	26±4.33

The mean BMI was shown as 26 kg/m^2 among selected adults. This data prove that the selected Adults were in the overweight category which indicates the lack of physical activity, being unaware of the diet pattern, and performing sedentary activity.

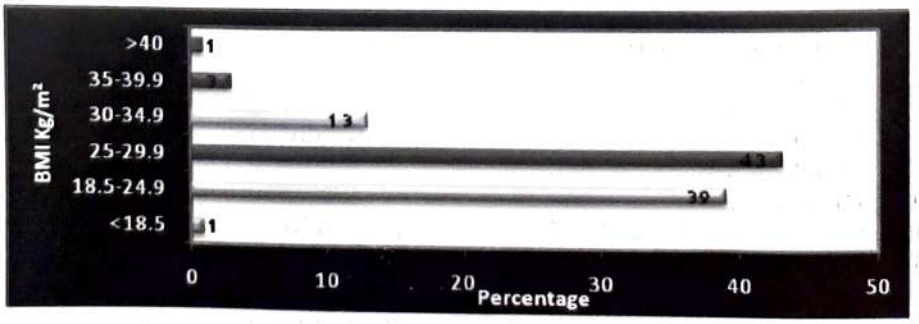
2. Body Mass Index (BMI)

Table 4 Classification of the selected adults according to body mass index

Classification		Number	Percentage
BMI	Category		
<18.5	Underweight	1	1
18.5-24.9	Normal	36	39
25-29.9	Overweight	39	43
30-34.9	Grade I obese	12	13
35-39.9	Grade II obese	3	3
>40	Grade III obese	1	1
Total	92	100	

*Global Data Base, WHO (2006)

Table 4 presents the classification of the selected Adults according to Body Mass Index categories recommended by WHO (2006). It is evident from the data that 39 per cent (36) of the selected Adults were in the normal category of BMI (18.5 to 24.9). Only a negligible number of respondents (1%) had a BMI less than 18.5 and are classified as underweight. A majority of 39 per cent (43) are overweight or obese.



Classification of the Selected Employees According to Body Mass Index (FIGURE 1)

Thirteen per cent (12) are classified as grade I obese followed by 3 per cent (3) who fall in the category of grade II obesity. Only one person among the selected Adults falls in the category of Grade III obesity

The results of BMI classification clearly point out that the majority of the subjects are either overweight or Obese. Overweight and obesity are number one causative factors for non communicable diseases.

3. BMI and physical activity analysis

Table 5 Correlation analysis of the BMI and physical activity of the selected adults (n=92)

Category	BMI
Physical activity	0.94*

*Significant at 0.05% level

Physical activity of the selected Adults was strongly correlated with the body mass index (BMI). This data shows that lack of physical activity and sedentary lifestyle was prevalent among the selected adults. This trend will lead to the incidence of metabolic syndrome and non-communicable diseases later.

D. Dietary perspective of the selected adults

According to Gopalan (2010) dietary surveys to assess dietary intake and nutritional status of the population are essential to monitor ongoing nutrition transition and initiate appropriate interventions.

1. Dietary Details

Type of diet of the selected adults show that 86 per cent were non-vegetarian. The selected adults consuming three meals per day were predominant. Twenty seven per cent had the habit of skipping at least one meal per week. The eating habits of the selected adults highlight that out of 92 adults, 49 per cent have the practice of eating quickly. This may be due to time pressure or they may be eating quickly from childhood itself. One has to give time for the brain to judge the fullness and slow eating helps for good digestion and reduces the risk of over eating and thus diabetes as a consequence.

Table 6 Dietary perspective of the selected Adults *(n= 92)*

Variables		No.	%
Type of Diet	Vegetarian	9	10
	Non-Vegetarian	79	86
	Ova-Vegetarian	4	4
Number of meals consumed	Two	6	7
	Three	83	90
	Four	3	3
Skipping Meal	Daily one meal	7	8
	Weekly one meal	13	14
	Weekly two meals	5	5
Habit of Fasting	A meal per day	1	1
	A meal per week	9	10
	A meal per month	8	9
Habits of Eating	Quick	45	49
	Moderate	29	32
	Slow	18	20
Quantity of Water Consumption Per Day	<4 glass	14	15
	4-8 glass	45	49
	>8 glass	33	36
Food Allergy	Brinjal	2	2
	Potato	3	3
	Cabbage	1	1
	Coconut	1	1
	Crab	1	1
	Tea	1	1

2. Food Consumption Pattern

Table 7 Frequency of food consumption pattern of the selected adults

Food items	Daily		Weekly		Occasionally		Never		Total	
	No	%	No.	%	No.	%	No.	%	No.	%
Cereals	92	100	-	-	-	-	-	-	92	100
Pulses	39	42	53	58	-	-	-	-	92	100
Legumes, Nuts and Seeds	13	14	34	37	11	12	34	37	92	100
Greens leafy vegetables	15	16	66	72	10	11	1	1	92	100
Other vegetables	88	96	4	4	-	-	-	-	92	100
Vitamin A rich fruits	17	18	50	54	7	8	18	20	92	100
Other Fruits	5	5	43	47	13	14	31	34	92	100
Roots &tubers	11	12	72	78	5	5	4	4	92	100
Fruits	41	45	38	41	11	12	2	2	92	100
Milk	24	26	5	5	3	3	60	66	92	100
Sugar and jaggery	82	89	-	-	3	3	7	8	92	100
Spices and condiments	38	41	53	58	-	-	1	1	92	100
Egg	4	4	49	53	27	29	12	13	92	100
Poultry	2	2	56	61	15	16	19	21	92	100
Meat	1	1	14	15	43	47	34	37	92	100
Fish	1	1	37	40	35	38	19	21	92	100

Table 7 analyses the food consumption pattern of the selected adults. It was found that rice was consumed as a prime food. Seventy two per cent of the adults consumed green leaves weekly once & a vegetable on a daily basis, but the quantity was very less. Roots and tubers (potato) were consumed on a daily basis by 12 per cent of the adults.

Enquiry about consumption of fleshy foods (Non vegetarian) indicated that fleshy foods were consumed weekly once by a majority of the subjects. Poultry consumption (61%) was greater than other fleshy foods followed by egg at 53 per cent, fish at 40 per cent and red meat at 14 percent respectively. The consumption of milk among selected adults was very poor. Eighty nine per cent of them consume sugar and sugar based products daily. Only eight per cent reported that they never consume sugar and jaggery products.

3. Consumption of junk foods

From Table 8 it was observed that the Forty nine per cent of the adults consumed fried items weekly once or twice, 17 per cent had on a daily basis and 27 per cent ate fried food occasionally. Other junk foods consumed by selected adults were Chat items (40%), baked items (25%), carbonated beverages (24%), pizza (11%), savories (5%) and burger (3%) respectively on an occasional basis.

Table 8 Consumption of junk foods by the selected adults

Food items	Daily		Weekly		Occasionally		Never		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Baked items	3	3	17	18	23	25	49	53	92	100
Chat items	-	-	15	16	37	40	40	43	92	100
Fried items	16	17	45	49	25	27	6	7	92	100
Sweets	5	5	20	22	55	60	12	13	92	100
Pizza	-	-	1	1	10	11	81	88	92	100
Savories	-	-	-	-	5	5	87	95	92	100
Burger	-	-	1	1	3	3	88	96	92	100
Carbonated beverages	-	-	6	6	22	24	64	70	92	100

4. Mean nutrient intake

Table 9 reflects the mean nutrient intake of the selected adults calculated from 24 hour recall survey.

Table 9 Mean nutrient intake of the selected adults

Nutrients	RDA*	Actual IntakeExcess/ deficit nutrient intake
Energy(K.cal)	2875	2210-665
Protein(g)	60	61+1
Fat(g)	20	44+24
Carbohydrate(g)	300	375+75
Fibre(g)	25	9-16
Calcium(mg)	400	598+198
Iron(mg)	28	15-13

*Dietary Guidelines for Indians- Amanual, NIN, ICMR, 2010

The data presented in Table 9 reveal that all the nutrients are consumed in adequate quantities whereas fibre and iron intake is inadequate. As the intake of green leafy vegetables and whole grains are lower in the daily diet, the fibre and iron contribution is also less.

5. Multivariate analysis

Table 10 Correlation for diabetes with various factors (n=92)

Category	PA	Age	BMI	FDH	QEH	JF
Diabetes	.71**	.70**	-.48**	.75**	.81**	.23*
Physical activity (PA)	-	.80**	.94*	-.54**	.81**	.32**
Age	-	-	-.65**	.53**	.85**	.50*
BMI	-	-	-	-.26**	-.64**	-.26**
Family Diabetics History (FDH)	-	-	-	-	.61**	.17*
Quick Eating Habits (QEH)	-	-	-	-	-	.45**
Junk foods (JF)	-	-	-	-	-	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

A Pearson produce moment correlation was conducted to examine the relationships amid Diabetes, Physical activity (PA), Age, BMI, Family Diabetes History (FDH), Quick Eating Habits (QEH), Junk Foods (JF) in selected adults with the number of Diabetes cases. Diabetes risk was more strongly positively related to Quick Eating Habits, r (90) = .81, p<.001, followed by Family Diabetes History, r (90) = .75, p<.001, Physical Activity, r (90) = .71, p<.001, Age, r (90) = .71, p<.001, Junk Food, r (90) = .23, p<.005. There was a significant negative association between diabetes and their BMI, r (90) = -.48, p<.005, than to Age, r (90) = -.65, p<.001, two-tailed. The results suggest that there was a statistically significant association between Diabetes, Physical activity, Age, BMI, Family Diabetes History, Quick Eating Habits, Junk Foods in selected adults. A complete list of correlation is presented in Table 10.

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CONCLUSION

The result of the current study has brought out the dietary status of the chosen adult subjects. The data indicates that majority of the adults are either over weight or obese putting them on the verge of non-communicable diseases such as obesity, cardio vascular disease, Type 2 diabetes, hypertension etc... This could be rectified through regular practice of consuming a nutritious and appropriate diet, indulging in physical exercise, practicing yoga and organizing program like nutritional awareness and education to all age groups of the adults.

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IOT based Smart Robot using Arduino

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ABSTRACT

Agriculture is the main profession for a majority of people living in India. So, advancement in the field of agriculture is directly proportional to the advancement of the nation. Also, making the process of agriculture automated makes it efficient, less prone to errors and more flexible. This research paper explains the development of the prototype of such a robot named Agrobot (agricultural robot). Agrobot is an IOT based designed for automatic ploughing of fields, seed sowing and irrigation of field's with solar panel as power source. As a result human efforts and time will be reduced as well as it runs on solar panel and technology which is a sustainable energy source. The increased usage of IoT has only led to more and more advances.

Keywords: Agriculture, Arduino, Electromechanical, Robotics, Solar Energy, Sensors.

The Agriculture in India is a source of employment for 50% of population in India. It contributes approximately 17% to 18% of India's GDP as of 2018 report (Kumar *et al.* 2018). Hence advancements in the field of agriculture will not only help improve the GDP but also pave the way for people to do more of smart work than manual work (Pandey *et al.* 2017). The tasks performed in agriculture, e.g. Seeding, harvesting, irrigation or ploughing are mainly manual jobs (Praseena *et al.* 2019). Making these tasks automatic or robotic based, saves a lot of time and manpower (Mutharasu *et al.* 2019).

All these saved human efforts could be then put up to other more important tasks. All these saved human efforts could be then put up to other more important tasks.

Some developing countries are still struggle with feeding their country on their own. And with this huge increase in population, the need to manage demand and supply increases many folds. The main concern related with this issue is of making enough resources available to feed them. This situation thus presents opportunities to make new inventions in this field.

Many inventions have been made in agricultural field and still more are welcome. From using trucks to drones – agriculture has evolved a long way and the invention of IoT has only paved the way for more complex yet very successful and useful devices.

The Internet of Things (IoT) was developed recently and very soon it has spread in almost every field. From manufacturing, health, IT sector, educational field, communications department, resource and energy to agriculture – IoT has its applications everywhere.

IoT has made the data handling and data surveillance very easy. Implementing IoT with appropriate sensors gives us an amazing device to implement all the resources efficiently that are available at our hand (Sominindia *et al.* 2019).

This paper presents prototype for such an agricultural robot. The AGROBOT is first of its kind. It performs the functions of harvesting, seeding and irrigation. The various features are integrated using Arduino UNO and interfacing it to Wi-Fi module. The Agrobot derives its power from solar panel and which is sustainable energy and makes use of various sensors such as ultrasonic, infrared, soil and moisture. Sending data from sensors to cloud helps to manage the field efficiently and easily. The sensors increase the accuracy of the device. Also, the sensors used are inexpensive, hence making the Agrobot is pretty cheap. The use of solar panel makes it an energy efficient device which is the need of hour in our global warming effected era. Using IoT, makes this an easy device for tracking and monitoring the developments in agricultural land. So, in this manner this paper contributes towards learning and contributing to the field of agriculture by

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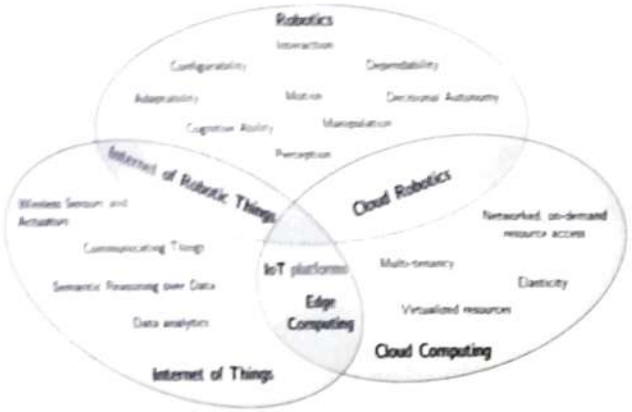

Figure 1 IoT+ Edge Computing + Cloud Computing+ Cloud Robotics+ Robotic (Nayyar *et al.* 2018).

the use of Internet of things.

The above figure properly depicts the architecture of Internet of Robotics Things (IoRT), in recent years. IOT operates in heterogeneous environment, where different IOT devices of different standards and specifications are mixed up, that's why IOT needs to provide high security for those devices because in wireless communication when data is transferring without any circuit medium it will be unsecured.

When Internet of Robotics Things, Robotics, Internet of things and cloud computing are mixed up in a Venn diagram, IOT provides end-to-end encryption and things become easy to operate (Sreelakshmi *et al.* 2016).

Considering the viewpoint of technology, the following technologies will assist Agrobot in performing complex tasks and operate in multi-dimensional environment:

Internet of things (IOT): IoT is the intersection of the digital and the physical world. IoT enhances the physical devices (Agrobot) with sensing, computing and communication capabilities (Ashwariya *et al.* 2019). These enhanced devices (Arduino or raspberry pi) are communicating with the digital world, producing data, send it to cloud.

Sensor networks: sensor networks are a group of sensors which are used for collecting useful data from the surrounding and sending them to servers or either remains up to user end.

Table 1 Literature Survey

S.No	TITLE OF PAPER	YEAR	FEATURES
1	Innovative Analysis of Precision Farming Techniques with Artificial Intelligence (Joseph et al. 2020)	2020	Harvesting, spraying, Mapping, Sensing
2	Machine Vision and Machine Learning for Intelligent Agrobots: A review (Bini *et al.* 2020)	2020	Harvesting, pest spraying
3	Design and implementation of AGROBOT using IOT (Mutharasu et al. 2019)	2019	Seed preparation
4	Using Sustainable Robotics in an Intelligent Robotic Gardening System for Education Araizal et al. 2019	2019	Gaming interface
5	Smart Agriculture Robot (Arun et al. 2018)	2018	ploughing,sowing of seeds, obstacle detection, obstacle clearance and irrigation.
6	Farmbot-a Smart Agriculture Assistor Using Internet of Things 1P (Hemalatha et al. 2018)	2018	Seeding, Harvesting, Ploughing
7	AgRobots (A combination of image processing and data analytics for precision pesticide use) (Kala et al. 2018)	2018	Seeding, Harvesting, Ploughing
8	Multipurpose Agricultural Robot (Kokate & Yadav 2017)	2017	Seeding, Irrigation, Fertilization
9	Versatile Agribot Using Solar Panel (Malini et al. 2016)	2016	Seeding, Digging, mud level, function, pesticide
10	Development of Agricultural and Seeding Equipment (Ramesh & Girishkumar 2014)	2014	seeding
12	Automated Irrigation System Using a Wireless Sensor Network and GPRS Module (Gutierrez et al. 2013)	2013	Irrigation

Previously, there have been made attempts to develop a robot that performs either of these functions. The previous attempts are available in many forms. Some of them are Electromechanical while some are IoT (Internet of Things) or embedded based and their references are given below. Table 1 shows a few examples of Arduino based agriculture robots that have been made in recent years.

MATERIALS AND METHODS

The main components of the prototype are represented with the help of the block diagram as shown in figure 2. Arduino is the heart of the Agrobot prototype design proposed in the paper. We used Arduino UNO for our design. All the connections between Arduino and the bot are made through the breadboard. The three major functions ploughing, seed sowing and irrigation of the Agrobot are performed by certain blocks represented as plougher, seed dispenser and irrigation respectively. The plougher is attached at the back end of the robot. It is connected with a servomotor. Plougher moves in up and down motion. When plougher is not used, we move it upwards and when it is required to plough, we keep it downwards.

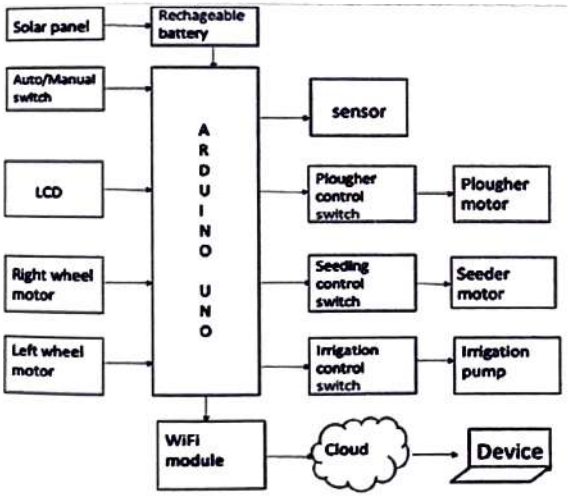

Figure 2 Block diagram of Agrobot

- Arduino uno: Arduino uno is a small board used for prototyping, with 14 digital input/output pins and 6 analog pins.
- Esp.8266: It is Wi-fi module interfaced with Arduino. It has 16 GPIO pins.
- Motor: It is used in seed dispenser so that the seeds will dispense one by one through it.
- Sensors: The Agrobot uses several sensors. Ultrasonic and infrared sensor is used to detect obstacles and for the movement if the bot. Soil moisture sensor is being used to measure the moisture content in the soil.
- Solar panel: It is an assembly of photo-voltaic cells to generate current. The Agrobot derives its power from here.
- LCD display: A 16x2 LCD screen is used for displaying information of the task being processed. It has 16 pins.
- Switch: It is used in either ON/OFF (HIGH/LOW) purpose. This is used to control the functions.
- Battery: Battery will supply the current to the whole circuit when the solar panel is not working.

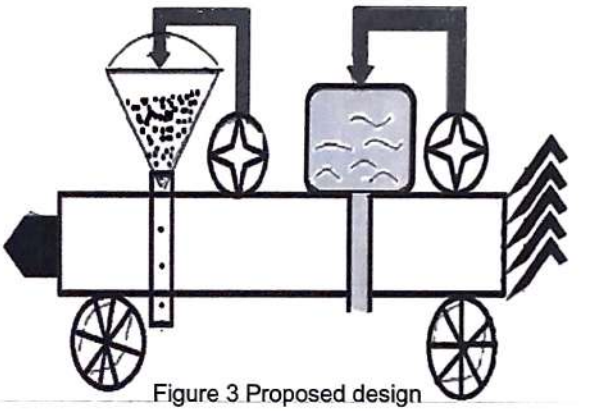

Figure 3 Proposed design

The Agrobot structure is made on a high – quality rectangular DMF board. Four wheels are connected to the board for Agrobot movement. Now on the back side of the Agrobot, a claw like structure is connected so that it works as a plougher. 2 holes are drilled on the left and right side of the bot. On the left-hand side on the top of the board, we mount a seed dispenser. This dispenser is attached to a dc motor to disperse off one seed at a time. On the right side we mount an irrigation pump. The irrigation pump is also connected to a dc motor to perform pumping.

On the front side of the Agrobot, there are various sensors placed. We use ultrasonic sensor, soil moisture and humidity sensor and one infrared sensor. In the upper middle part, we have base for Arduino interfaced with Wi-Fi module which will send the data to cloud so that farmers can monitor their field. Then we attach another DMF board on top of this existing board. On this second layer, we install our solar panel. Detailed description of each function is as follows:

a) Source of Power: The bot derives its power from

the rechargeable battery and battery is connected to solar panel which is mounted on the top. So the Agrobot performs even in the absence of sunlight.

b) Ploughing: A plougher is attached at the end of the Agrobot. Whenever the command for plougher is given, the plougher pulls down and starts performing. When not in use it is pulled up.

c) Seeding: We have a seed dispenser for this purpose. The dispenser is connected to a dc motor. The dispenser is a box which has a rotating shaft inside it. The DC motor helps rotating the shaft. The seed box has a funnel in the lower portion which through a hole goes inside the bot. So, when seeding is performed, the shaft rotates and one seed comes at a time through the funnel.

d) Irrigation: A small water tank is connected to a dc motor which has a pipe below it that runs to the end of the Agrobot through a hole. When the irrigation process is selected, the Agrobot first checks the data of all sensors. We have used soil moisture and humidity sensor for this purpose. They read the values of moisture and humidity present in the soil and compare it with a pre set threshold value. The threshold value can be set by the user according to the crop, type of soil, weather and such affecting points. When the value is lower than threshold value, the process of irrigation begins. The motor pumps water from tank to the pipe and then to the soil. But if the values from sensors are greater than threshold values, then no irrigation is performed.

e) Movement: There are four wheels and one ultrasonic sensor to control the movement of the bot. The ultrasonic sensor detects hindrances in the path of the Agrobot whenever any obstacle is detected; the Agrobot is configured to change its path.

f) Surveillance: We have mounted one infrared sensor at the front end of the bot. In this way, we can monitor the field for intruders at any time in the field.

g) Configuration: All the above functions are integrated through Arduino UNO and Wi-Fi module. Each function is switch enabled. Connecting the Arduino board with a wi-fi module, takes this device to next level. It will gather their data and send it to user end. We can now control and manage our operations over phone. If in a field there are multiple such robots, the data can be transferred to Cloud and then handled easily.

RESULTS AND DISCUSSION

The Agrobot has the advantage of being the first device that integrates all three functions – ploughing, seeding and irrigation. The use of solar panel makes it energy efficient. In the times when energy and fuel are of much conservative importance, this device seems to be very helpful. The devices used are relatively cheaper. This makes the overall bot inexpensive. The sensors perform the task with accuracy and precision. The use of sensors to check whether irrigation is needed or not, somewhere saves water. Making the whole process automated means the task can be done 24*7. Human error and boredom will not be a threat to a machine. Using IoT, huge areas can be monitored. Even in smaller fields, the user can manage all the operation using his phone. This agricultural robot is a new kind of robot integrating all the features in one device. This makes agricultural processes very efficient and accurate. Including the aspects of IoT makes it truly a coming of age device. This not only widens the areas of use, but this also makes the tasks of monitoring and security very easy. Using IoT and sensors, the tasks which previously required physical monitoring can now be done online through any handset with good internet connection. The prototype image is shown in figure 4 and figure 5.

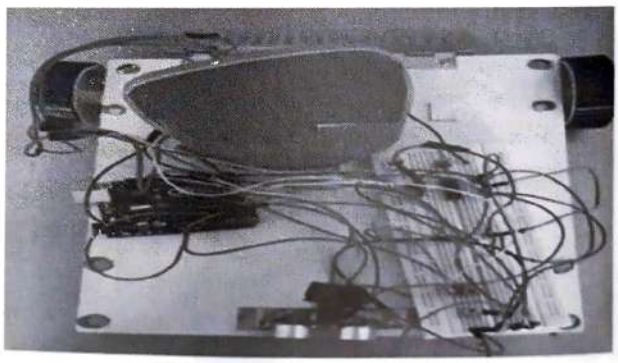

Figure 4 Agrobot Prototype (top view)

Figure 5 Agrobot Prototype (Side View)

Efficiency of the proposed design is better as compared to design developed in previous years in terms of range, due to increase of equipped IoT

devices and sensors as shown in figure 6.

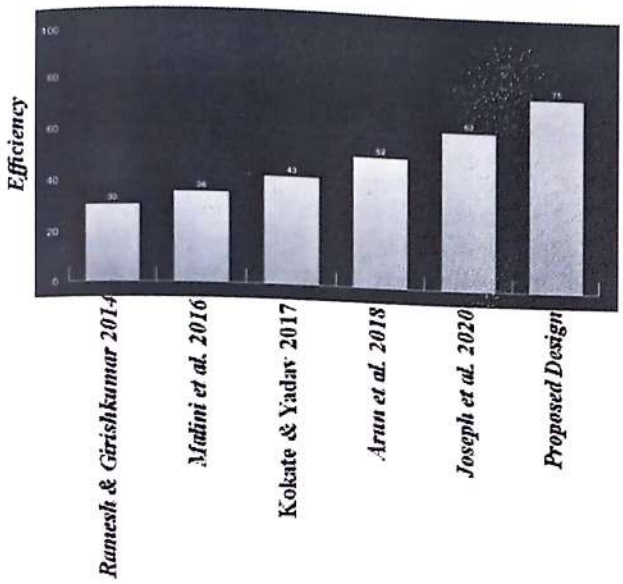

Figure 6 Efficiency of developed Agrobot

The range is increased three times and its efficiency is increased upto 75%. The Agrobot is already ahead of its time. But we can still make moderate changes in it. Pest control mechanisms can be implemented in it. Pesticide can be sprayed through sprinklers. Bug and worms can be detected using various kinds of sensors. An alarm system can also be installed in the bot. To monitor huge acres of farming land, the physical structure can be modified of this bot. Instead of wheels, the Agrobot can be made as a drone. But changing the structure to drone would mean, removing the ploughing feature.

Technology wise, the IoT structure of the robot can be scaled. Developing an IoT structure through GCP or related programs, the monitoring and tracking feature can be increased to a great level. We can also include ML (Machine Language) at the edge.

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Influence of abiotic factors on activity of insect pests and their predators in sesame

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ABSTRACT

Study on population dynamics of sesame pests and their natural enemies was carried out at Agronomy farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during summer and *kharif* 2015. Population of whitefly was higher in both summer and *kharif* seasons, whereas incidence of leaf webber was noticed only during *kharif* season. Population of other pests' viz., leafhopper, mirid bug and hawk moth as well as predatory fauna such as chrysopids, coccinellids and spiders were less during the study period. Peak activity of whitefly was observed during 17th standard week (4th week of April) and on 36th standard week (1st week of September) during summer and *kharif*, respectively. The activity of leaf webber reached to peak level during 38th standard week (3rd week of September) during *kharif* season. The maximum and minimum temperature, maximum vapour pressure, morning and evening wind direction as well as evaporation had highly significantly positive association, whereas minimum vapour pressure had significantly positive association with whitefly population on sesame in summer season. During *kharif* season, minimum vapour pressure and evening wind direction had significantly positive correlation.

Key words : Sesame, pest activity, predators, weather parameters, correlation

Sesame (*Sesamum indicum* Linnaeus), also known as the "queen of oil seeds", is an important oil seed crop grown in India. It contains approximately 52 to 57% oil and 25% protein (Smith *et al.*, 2000; Khan *et al.*, 2009; Umar *et al.*, 2010). India is the second largest producer of sesame seed with a production of 7,55,346 Metric Tons and Myanmar topped the ranking with 7,85,038 Metric Tons in 2019. However, in harvested area, India ranks first with 1,732,975 Hectares. In India, sesame production has increased from 746 Metric Tons in 2018 to 7,55,346 Metric Tons in 2019 (Anon., 2019_a). Export of this important oilseed crop has declined from 336.85 tonnes in 2017-18 to 312.00 tonnes in 2018-19 and import has increased from 26.27 tonnes (2017-18) to 87.54 tonnes (2018-19) (Anon., 2019_b). India produces a wide variety of sesame seeds varying in colour from white to red to black. The major Indian states producing sesame are Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Madhya Pradesh and Maharashtra.

There is a great need to boost up the productivity of sesame but insect pests are one of the major constraints in enhancing it. This crop is reported to be damaged by 29 insect pests (Rai, 1976), however, due to the changed cropping pattern, the insect pest complex has increased to about 65 including one mite species (Ahuja and Bakhetia, 1995). Insect pests of sesame having national significance includes, leaf webber or roller and capsule borer, *Antigastra catalaunalis* Duponchel; gall fly, *Asphondylia sesame* Felt and leafhopper, *Orosius albicinctus* Distant. Insect pests *viz.*, sphinx moth or hawk moth, *Acherontia styx* Westwood; Bihar hairy caterpillar, *Spilosoma obliqua* Walker; red hairy caterpillar, *Amsacta albistriga* Walker; pod bug, *Elasmolomus sordidus* Fabricius; pentatomid bug, *Nezara viridula* (Linnaeus) and cotton aphid, *Aphis gossypii* Glover are of regional significance in India (Anon., 2014). These pests damage the crop at different stages of growth affecting both quality and quantity resulting in heavy loss (25 - 90%) in seed yield (Ahuja and Kalyan, 2002). Global changes, which include climate change among the wide range of anthropogenic and natural environmental variation could profoundly affect the population dynamics and status of insect pests of crops (Khaliq *et al.*, 2014). Therefore, it is imperative to study the population fluctuation of the crop pests in relation to weather parameters that largely direct the activity of

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a given species of insect pest. Keeping in view the economic importance of the crop and magnitude of the damage caused by various insect pests, the study on population build-up of major insect pests and their natural enemies in sesame was undertaken.

MATERIALS AND METHODS

A field trial was carried out at Agronomy farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during summer and *kharif,* 2015 on sesame variety G. TIL-3. The crop was raised by adopting the standard agronomical practices. Experiment was laid in an area of 20 × 10 m and with a spacing 45 × 10 cm. The whole experimental plot was divided into four sectors and five plants from each sector were selected for recording the observations. The plots were kept free from insecticidal spray throughout the crop period.

Incidence of different insect pests was recorded at weekly interval from germination to harvesting of the crop. For recording observations on number of nymphs and adults of sap feeders *viz.*, white fly, *Bemisia tabaci*; leafhopper, *Orosius albicinctus* and mirid bug, *Nesidiocoris tenuis*, three leaves (upper, middle and lower) from each five randomly selected plants were examined. Population of defoliators' *viz.*, leaf webber, *Antigastra catalaunalis* and hawk moth, *Acherontia styx* were recorded from five randomly selected plants per sector. Plants were critically observed at weekly interval from germination till harvesting of the crop. Natural enemies' *viz.*, coccinellids, chrysopids and spiders were also recorded from the randomly selected plants.

Data recorded on insect pests and meteorological parameters were statistically analysed. Correlation study was done in order to determine the population dynamics of insect pests and their natural enemies, the periodic mean incidence of the major insect pests and their natural enemies were worked out. Meteorological data during crop period was obtained from the Department of Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand. Simple correlation was computed between population of these insect pests, damage indices and abiotic factors *viz.*, evaporation, bright sunshine, rainfall, morning wind direction, evening wind direction, wind speed, maximum and minimum temperatures, maximum and minimum relative humidity and maximum and minimum vapour pressure.

RESULTS AND DISCUSSION

Population of whitefly was higher in both summer and *kharif* seasons, whereas incidence of leaf webber was noticed only during *kharif* season. Population of other pests like, leafhopper, mirid bug and hawk moth as well as predatory fauna such as, chrysopids, coccinellids and spiders were less during the study period.

Whitefly, B. tabaci

Activity of whitefly started from 9th standard week *i.e.* 1st week of March during summer and from 32nd standard week *i.e.* 2nd week of August during *kharif* and continued till harvest of the crop in both the seasons. Peak activity of the pest was during 17th standard week *i.e.* 4th week of April (2.52 whiteflies/ 3 leaves) and on 36th standard week (0.43 whitefly/3 leaves) *i.e.* 1st week of September during summer (Table 1) and *kharif* (Table 2), respectively.

The correlation coefficient analysis (Table 3) of whitefly population in summer season revealed that maximum and minimum temperature, maximum vapour pressure, morning and evening wind direction as well as evaporation had highly significantly positive association (r = 0.915**, 0.910**, 0.880**, 0.782**, 0.762** and 0.833**, respectively), whereas minimum vapour pressure had significantly positive relation (r = 0.602*) with whitefly population on sesame. In *kharif* season, minimum vapour pressure (r = 0.577*) and evening wind direction (r = 0.639*) had significantly positive association.

Earlier reports of higher populations of *B. tabaci* during 35th to 36th standard week reported by Ahirwar *et al.* (2009); Kumar *et al.* (2010) and Choudhary *et al.* (2015) strongly support the present findings.

Leafhopper, O. albicinctus

Population of *O. albicinctus* first appeared on sesame crop from 12th standard week *i.e.* 4th week of March and remained constant till 15th standard week *i.e.* 2nd week of April (Table 1). The pest reached to a peak level (0.25 leafhopper/ 3 leaves) on 18th standard week *i.e.* 1st week of May. Minimum incidence of leafhopper was observed during *kharif* (Table 2) and the activity was noticed only for few weeks. The pest first appeared (0.05 leafhopper/ 3 leaves) from 36th standard week (1st week of September) and reached the peak level (0.15 leafhopper/ 3 leaves) on 37th standard week (2nd week of September).

Ahirwar *et al.* (2009) and Choudhary *et al.* (2015)

Table 1 Population fluctuation of insect pests and natural enemies in sesame during summer, 2015

SMW	Month	Week	No. of sucking insect pests/ 3 leaves			No. of predators/ plant		
			Whitefly	Leafhopper	Mirid bug	Coccinellid	Chrysopid	Spider
9	March	1	0.20	-	-	-	-	-
10		2	0.58	-	-	-	-	-
11		3	0.82	-	-	-	-	-
12		4	2.00	0.10	0.40	-	-	-
13		5	2.12	0.10	0.30	-	-	-
14	April	1	2.28	0.10	0.20	-	-	-
15		2	2.30	0.10	0.10	-	-	-
16		3	2.46	0.05	-	0.05	0.10	-
17		4	2.52	0.20	-	0.05	0.05	0.05
18	May	1	2.50	0.25	-	0.05	0.10	0.05
19		2	2.44	0.15	-	0.05	0.05	0.05
20		3	2.38	0.10	-	-	-	0.05

noticed the higher incidence of *O. albicinctus* in between 32nd and 37th standard weeks.

Mirid bug, N. tenuis

The data (Table 1) on population of mirid bug indicated that, it appeared only for four weeks during crop period in summer with a population of 0.40, 0.30, 0.20 and 0.10 mirid bug/ 3 leaves during 12th, 13th, 14th and 15th standard weeks (4th and 5th week of March and 1st and 2nd week of April). Population of *N. tenuis* indicated that the activity was less in *kharif* season as well (Table 2). Pest appeared (0.10 mirid bug/ 3 leaves) during 37th standard week (2nd week of September) and disappeared in the 38th standard week (3rd week of September). However, the pest appeared again in the crop during 39th *i.e.* 4th week of September with a population 0.05 mirid bug per three leaves.

Leaf webber, A. catalaunalis

Population of leaf webber first appeared (2.10 larvae/ plant) on sesame crop from 32nd standard week *i.e.* 2nd week of August and continued till harvesting of the crop *viz.*, 43rd standard week (Table 2). The activity of *A. catalaunalis* gradually increased from 33rd standard week (3rd week of August) and reached to peak level (4.20 larvae/ plant) during 38th standard week (3rd week of September). Leaf damage caused by leaf webber was 20.13 per cent on sesame crop from 32nd standard week (2nd week of August) and continued till maturity of the crop (3rd week of October). Damage gradually increased and reached to peak (31.88 %) on 40th standard week (1st week of October). The flower damage was observed only for five weeks and it started from 38th standard week and continued till maturity of the crop (3rd week of October). Peak (30.08 %) flower infestation was noticed on 41st standard week (2nd week of October). The capsule damage was noticed only for five weeks which started from 38th standard week and continued till maturity of the crop (3rd week of October). The highest (28.87 %) capsule damage was recorded on 42nd standard week (3rd week of October).

Leaf webber showed non-significant positive correlation (Table 3) with minimum temperature, minimum relative humidity, maximum and minimum vapour pressure, morning and evening wind direction, wind speed, rainfall, bright sunshine and evaporation (r = 0.229, 0.351, 0.301, 0.385, 0.350, 0.340, 0.284, 0.415, 0.088 and 0.006, respectively). Negative but non-significant correlation was noticed between leaf webber population and maximum temperature (r = -0.269) and maximum relative humidity (r = -0.150).

Peak activity of *A. catalaunalis* was observed on sesame during 35th to 37th standard week (Ahirwar *et al.*, 2009 and Choudhary *et al.*, 2015). These reports are almost similar to the present findings.

Hawk Moth, A. styx

Incidence of hawk moth was not noticed during the summer season, however pest appeared in *kharif* season (Table 2). Incidence of hawk moth was very less and it appeared only for three weeks with a mean population ranging from 0.25 to 0.75 larvae/ plant during 38th to 40th standard weeks.

Activity of natural enemies in sesame

In summer season (Table 1), coccinellids and chrysopids were found during 16th to 19th standard

Table 2 Population fluctuation of insect pests and natural enemies in sesame during kharif, 2015

SMW	Month	Week	No. of sucking insect pests/ 3 leaves			No. of predators/ plant			No. of larvae/ plant		Damage (%) due to *A. catalaunalis*		
			Whitefly	Leafhopper	Mirid bug	Coccinellid	Chrysopid	Spider	Hawk moth	Leaf webber	Leaf	Flower	Capsule
32	Aug	2	0.18	-	-	-	-	-	-	2.10	20.13	-	-
33		3	0.26	-	-	-	-	-	-	2.38	21.98	-	-
34		4	0.32	-	-	-	-	-	-	2.56	23.30	-	-
35		5	0.40	-	-	-	0.05	0.10	-	3.06	25.58	-	-
36	Sep	1	0.43	0.05	-	-	0.05	0.05	-	3.70	29.06	-	-
37		2	0.42	0.15	0.10	-	0.03	-	-	4.08	31.13	-	-
38		3	0.40	-	-	0.05	-	-	0.75	4.20	31.38	22.82	20.76
39		4	0.35	0.10	0.05	0.10	0.03	0.10	0.50	4.00	31.53	26.23	23.57
40	Oct	1	0.30	0.10	-	0.05	0.10	0.10	0.25	3.38	31.88	27.53	27.46
41		2	0.26	0.05	-	0.05	0.05	0.10	-	3.02	30.36	30.08	28.68
42		3	0.20	-	-	0.05	0.03	0.10	-	2.18	27.87	28.23	28.87

Table 3 Correlation between abiotic factors and incidence of insect pests of sesame

Abiotic factors		Correlation coefficient (r)		
		Summer	Kharif	
		Whitefly	Whitefly	Leaf webber
Evaporation (mmday-1), EP		0.833**	0.153	0.006
Bright Sunshine (hrsday-1), BSS		0.550	-0.004	0.088
Rainfall (mm), RF		-0.486	0.292	0.415
Morning Wind Direction, WD1		0.782**	0.530	0.350
Evening Wind Direction, WD2		0.762**	0.639*	0.340
Wind Speed (Kmhr-1), WS		0.439	0.470	0.284
Temperature (0C)	Max	0.915**	-0.367	-0.269
	Min	0.910**	0.447	0.229
Relative Humidity (%)	Max	-0.376	-0.060	-0.150
	Min	-0.552	0.481	0.351
Vapour Pressure (mm)	Max	0.880**	0.513	0.301
	Min	0.602*	0.577*	0.385

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

week (3rd week of April to 2nd week of May). The spider population was noticed from 17th to 20th standard weeks (4th week of April to 3rd week of May). Population of chrysopid and spider remained constant (0.05 chrysopid/ plant and 0.05 spider/ plant) from 16th to 19th standard week (3rd week of April to 2nd week of May) and 17th to 20th standard weeks (4th week of April to 3rd week of May), respectively. Population of chrysopid fluctuated between 0.05 and 0.10 chrysopid per plant in alternative weeks.

During *kharif* season (Table 2), chrysopid and spider population was observed from 35th standard week (5th week of August), whereas, coccinellid from 38th standard week (3rd week of September) till harvesting of the crop (42nd standard week). Population of coccinellid remained constant (0.05 coccinellid/ plant) except during the peak (0.10 coccinellid/ plant) period. Chrysopid population fluctuated between 0.03 and 0.10 per plant with a peak of 0.10 chrysopid per plant. The mean spider population varied from 0.05 to 0.10 per plant.

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