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Evaluation of Integrated Pest Management Module against Pests of Ground Nut and Productivity, Profitability Analysis under Open Field Conditions

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ABSTRACT

Background: Groundnut is an annual oilseed crop that is cultivated in many tropical and sub-tropical countries for its seed purpose. The productivity of groundnut has drastically reduced since 2015 due to an array of insect pests especially sucking pests have emerged as a prominent factor contributing to decreased yields in groundnut by direct damage as well as vectors of virus diseases.

Methods: The integrated package of practices including seed treatment with fungicide (mancozeb @ 3 g/kg seed) followed by insecticide (imidacloprid @ 2 mL/kg seed) and new generation insecticides (imidacloprid, chlorpyriphos and flubendiamide) were evaluated against sucking pests (aphid, leaf hopper and thrips) and leaf feeders (*Spodoptera litura*) under open field conditions in scarce rainfall zone of Andhra Pradesh, India during 2020-21, 2021-22 and 2022-23. The parameters regarding incidence of pests, population reduction after treatment imposition, safety to natural enemies, phytotoxicity effects, extension gap, technology gap and technology index, were worked out in farmer's field and demonstration field.

Result: In this present study imidacloprid 17.8 SL was performed well in controlling aphids, leaf hoppers and thrips in all the three seasons and flubendiamide 39.35 SC was concluded as best treatment against *Spodoptera litura* in all seasons. During all the study years, the benefic cost ratio of demo practice indicates (1.26, 1.01 and 1.04) when compared to farmers practice (0.71, 0.69 and 0.76), respectively for 2020, 2021 and 2022. Similarly, the average extension gap, technology gap and yield gap were worked out and ranged from (3.4, 3.1 and 5.3), (1.82, 4.23 and 1.82), (12.72, 11.36 and 19.46) for the years 2020, 2021 and 2022, respectively.

Key words: Bio-efficacy, Extension gap, Groundnut, Integrated pest management, Productivity.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a nutrient-rich oilseed legume, is the sixth most important contributor to edible oil and the third most important source of vegetable protein in the world (Lenka *et al*., 2023). India stands first in Groundnut area (54.20 lakh ha.) and the second biggest producer in the world with 101 lakh tones of production and 1863 kg ha^{-1} productivity in 2021-22 (Yadav *et al*., 2023). Andhra Pradesh cultivates groundnut on an area of 8.23 lakh hectares and producing 5.19 lakh tons that contributing 6.20% to India's groundnut production for the year 2021-22 (des.ap.gov.in). But a large gap between the potential and actual yield was observed in groundnut production system due to major constraints *viz.* lower yield, destructive pest and diseases, rainfall and moisture, labour intensive, more variations in market price. Due to a lack of awareness about the most recent enriched technologies among groundnut farmers, the competency gap is a key factor in enhancing production and sustainability. Hence there is an immediate need to replace traditional cultivation practices with smart cultivation practices through Frontline Demonstrations (FLDs). FLDs are a novel strategy with the goal of performing demonstrations in wider areas on farmers' fields and raising farmer knowledge about the sustainable crop production technology with a low cost (Amuthaselvi *et al*., 2023). To the best of our knowledge, no studies have been documented in Andhra Pradesh, specifically within the Scarce Rainfall Zone (SRZ), that focus on groundnut frontline demonstrations (FLDs) in incorporating the modern production technologies. Therefore, the

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current study was carried out to design and execute a planned of advanced technologies through FLDs at various locations of the Ananthapuramu district in order to deliver the farmers with healthy net returns.

MATERIALS AND METHODS

Three field experiments were conducted in the farmer fields of Krishi Vigyan Kendra, Reddipalle during the year 2020-21, 2021-22 and 2022-23 against insect pests of groundnut with Integrated Pest Management (IPM) modules, toxicity to natural enemies and phytotoxic effect. The series of IPM practices (Table 1) were practiced in the selected farmer plots (10) for three consecutive years. Aphid populations were counted on the top 2 cm shoot length of 5 randomly selected plants in each plot and thrips were counted on the top three bud leaves of 5 randomly selected plants in each plot before the second application of insecticide at 3, 5 and 10 days after treatments. Five randomly chosen plants from each treatment were examined for the total number of spodoptera larvae on their top, middle and bottom leaves one day prior to treatment and three, seven and fourteen days following the first and second applications of insecticides. Likewise, natural enemies such as *Cotesia plutellae* Kurdjumov, *Chrysoperla carnea* Steinmann occurring in the field were counted one day before treatments and on the 15th day after each spray. The per cent control of leaf hoppers, thrips, aphids and *Spodoptera litura* over untreated control was calculated as suggested by Rajashekhar *et al.* (2022).

Before analysis, the population number were transformed into square root values. The results of field experiments were analyzed using a randomized block design (RBD) (Gomez and Gomez, 1984). Duncan's multiple range test (DMRT) was used to separate the mean values (Duncan, 1951). Assessment of phytotoxic effect of selected insecticides was evaluated by conducting field experiment in RBD with five replications and the plot size of 50 m^2. According to the Central Insecticide Board Registration Committee (CIBRC) protocol, symptoms of phytotoxicity, such as leaf damage, wilting, vein clearing, necrosis, yellowing, stunting, epinasty and hyponasty, were noted at 5, 10, 15, 20 and 30 days after treatments. A visual rating system of 0-10 was used to assess the symptoms of phytotoxicity: 0- No phytotoxicity; 1-10%; 2-11-20%; 3-21-30%; 4-31-40%; 5-41-50%; 6-51-60%; 7-61-70%; 8-71-80%; 9-81-90% and 10-91-100%. Per cent of leaf damage was calculated by using the following formula.

The gaps were categorized into three groups and given scores like full adoption (No Gap)-1, partial adoption (partial gap) -2 and no adoption (Full gap)-3 scores, respectively. Using a random crop cutting technique, the yield data were gathered from the farmers' practice and the demonstration and basic statistical tools were used for analysis. Adoption gap index was computed utilizing the Rajasekhar *et al.* (2022) formula.

The yield parameters from the farmer practices check and the demonstrations were noted. Technology index, yield gap, technology gap and extension gap were computed as a procedure using the yield parameters suggested by Rajashekhar *et al.* (2022) and Samui *et al.* (2000).

RESULTS AND DISCUSSION

Imidacloprid 17.8 SL @ 0.3 mL L^{-1} performed well in controlling leaf hoppers (mean population of all day's observation- 0.80, 1.07, 0.93/plant) with reduction over control were 82.60, 73.33 and 77.77% over three years (2020-2022), respectively (Table 2) Similarly, imidacloprid 17.8 SL @ 0.3 mL L^{-1} performed well in controlling aphids (7.83, 7.87and 8.07/plant) with reduction over control of 75.52, 75.56 and 77.21% over three years of 2020, 2021 and 2022, respectively (Table 3) followed by chlorpyriphos 50 EC (11.40, 11.87, 10.87/plant) with reduction over control of 67.24, 64.04 and 66.06%. Similarly, imidacloprid 17.8 SL @ 0.3 mL L^{-1} was effective in controlling groundnut aphid, with reductions over control of 72.13, 76.02 and 83.59% over three years (2020-2022), as shown in Table 4. Chlorpyriphos 50 EC, which had reductions over control of 70.17%, 67.21% and 58.19% over three years (2020-2022), was the next best option. Both imidacloprid 17.8 SL @ 0.3 mL L^{-1} and chlorpyriphos 50 EC @ 2 mL L^{-1} were found significantly more or less on par each other in controlling aphids based on percent reduction over control. Results revealed that *S. litura* treated with flubendiamide 39.35 SC (Table 5) was highly effective against leaf eating caterpillar (1.53, 1.33, 1.50/plant) with reduction over control of 83.33, 85.50 and 82.55% followed by chlorpyriphos 50 EC (7.40, 7.27, 7.53/plant) with reduction over control of 22.91, 22.69 and 21.53% on three consecutive years (2020-2022), respectively. The safety of insecticides to natural enemies

Table 1: Difference between technological intervention through Front line demonstration (FLD) in Groundnut.

Technology intervention	Farmers practices	Gap
Seed treatment with mancozeb and thiamethoxam 30 FS	Not followed	Full gap
Installation of *S. litura* pheromone traps	No pheromone traps used	Full gap
Installation of yellow sticky traps @ 30/acre	No sticky traps used	Full gap
Azadirachtin 10000 ppm spray 35-45 DAS to kill eggs of leaf feeders	Followed rarely	Partial gap
Use of bio-formulation *Baeuevaria Bassiana*	Followed rarely	Partial gap
Use of CIBRC registered and effective chemicals *viz.,* imidacloprid 17.8 SL and Flubendiamide 39.39 SC	Indiscriminate use of insecticides with similar mode of action	Partial Gap

Table 2: Evaluation of insecticides against leafhopper in ground nut.

Treatments	2020 season					2021 season					2022 season				
	PTC	1 DAT	3 DAT	5 DAT	PRC	PTC	1 DAT	3 DAT	5 DAT	PRC	PTC	1 DAT	3 DAT	5 DAT	PRC
Imidacloprid	4.60	0.40	0.60	1.40	82.60	4.00	0.60	1.00	1.60	73.33	4.20	0.20	0.80	1.807	7.77
	(2.14)	(0.91)c	(1.01)c	(1.14)b		(1.99)	(0.98)c	(1.19)b	(1.22)b		(2.04)	(0.81)c	(1.08)c	(1.31)b	
Chlorpyriphos	4.60	1.80	2.20	3.80	43.47	5.00	2.20	2.40	4.40	40.00	5.20	2.00	2.00	4.80	43.58
	(2.14)	(1.49)b	(1.62)b	(1.94)a		(2.23)	(1.62)b	(1.67)b	(2.09)a		(2.27)	(1.55)b	(1.56)b	(2.18)a	
Control	5.20	4.20	4.60	4.80	-	4.40	4.80	4.80	4.80	-	4.40	4.60	4.60	5.00	-
	(2.27)	(2.16)a	(2.25)a	(2.18)a		(2.09)	(2.29)a	(2.29)a	(2.18)a		(2.08)	(2.25)a	(2.24)a	(2.23)a	
S.Em	-	0.08	0.03	0.02	-	-	0.09	0.05	0.04	-	-	0.03	0.02	0.01	-
CD at 0.05	NS	0.339	0.187	0.272	-	NS	0.422	0.497	0.271	NS	NS	0.492	0.404	0.254	-

PTC- Pretreatment count; DAT- Days after treatment; PRC- Per cent reduction over control; Values in parentheses are square root (x + 0.5) transformed values In a column means followed by a common letter are not significantly different by DMRT (P= 0.05).

Table 3: Evaluation of insecticides against aphids in ground nut.

Treatments	2020 season					2021 season					2022 season				
	PTC	3 DAT	5 DAT'	10 DAT	PRC	PTC	3 DAT	5 DAT'	10 DAT	PRC	PTC	3 DAT	5 DAT'	10DAT	PRC
Imidaacloprid	32.00	5.40	7.60	10.50	75.52	32.20	4.80	7.80	11.00	75.56	35.40	4.60	9.40	10.20	77.21
	(5.65)^{b}	(2.31)b	(2.75)c	(3.23)b		(5.67)b	(2.18)c	(2.79)c	(3.31)c		(5.94)a	(2.41)b	(3.05)c	(3.18)c	
Chlorpyriphos	34.80	7.40	12.80	14.00	67.24	33.00	7.00	12.60	16.00	64.04	32.40	6.40	11.40	14.80	66.46
	(5.89)^{ab}	(2.70)b	(3.57)b	(3.73)b		(5.74)b	(2.63)b	(3.53)b	(3.99)b		(5.69)b	(2.43)b	(3.37)b	(3.84)b	
Control	33.20	37.40	38.00	42.40	-	37.20	38.20	42.60	44.60	-	34.20b	37.40	37.80	42.00	-
	(5.76)^{a}	(6.12)a	(6.61)a	(6.51)a		(6.09)a	(6.18)a	(6.52)a	(6.67)a		(5.84)a	(5.42)a	(6.14)a	(6.48)a	
S.Em	0.03	0.01	0.04	0.03	-	0.03	0.02	0.01	0.05		0.01	0.03	0.05	0.02	-
CD at 0.05	0.182	0.393	0.297	0.185	-	0.107	0.276	0.254	0.242	-	0.172	0.311	0.315	0.257	-

PTC- Pretreatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are square root (x + 0.5) transformed values In a column means followed by a common letter are not significantly different by DMRT (P=0.05).

Table 4: Evaluation of insecticides against thrips in ground nut.

Treatments	2020 season					2021 season					2022 season				
	PTC	3 DAT	5 DAT'	10 DAT	PRC	PTC	3 DAT	5 DAT'	10 DAT	PRC	PTC	3 DAT	5 DAT'	10DAT	PRC
Imidacloprid	13.40	1.00	4.20	6.00	72.13	12.20	0.80	4.40	6.80	76.02	25.60	1.60	4.40	6.60	83.59
	(3.65)	(1.19)c	(2.04)c	(2.43)c		(3.48)	(1.08)c	(2.06)c	(2.60)c		(5.05)	(1.24)c	(2.09)c	(2.56)c	
Chlorpyriphos	11.40	7.40	9.60	14.80	70.17	11.40	7.20	10.20	14.20	67.21	24.40	7.20	10.20	13.20	58.19
	(3.37)	(2.81)b	(3.09)b	(3.84)b		(3.37)	(2.77)b	(3.18)b	(3.76)b		(4.93)	(2.68)b	(3.19)b	(3.62)b	
Control	12.60	14.00	19.00	23.00	-	13.00	12.00	19.60	23.60	-	25.40	25.20	26.20	24.00	-
	(3.54)	(3.83)a	(4.42)a	(4.79)a		(3.59)	(3.52)a	(4.42)a	(4.85)a		(5.03)	(5.01)a	(5.11)a	(4.89)a	
S.Em	0.04	0.03	0.05	0.06	-	0.02	0.05	0.03	0.09		0.03	0.02	0.03	0.01	-
CD at 0.05	NS	0.338	0.207	0.377	-	NS	0.347	0.254	0.165		NS	0.256	0.177	0.242	-

PTC- Pretreatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are square root (x + 0.5) transformed values In a column means followed by a common letter are not significantly different by DMRT (P=0.05).

Table 5: Evaluation of insecticides against *spodoptera litura* in ground nut.

Treatments	2020 season					2021 season					2022 season				
	PTC	3 DAT	7 DAT'	14 DAT	PRC	PTC	3 DAT	7 DAT'	14 DAT	PRC	PTC	3 DAT	7 DAT'	14 DAT	PRC
Flubendiamide	9.20	0.60	1.40	2.60	83.33	9.20	0.40	1.20	2.40	85.50	8.60	0.20	1.60	2.70	82.55
	(17.64)b	(3.95)c	(6.69)c	(9.23)c		(17.64)b	(3.06)c	(5.80)c	(8.75)c		(17.04)b	(2.17)c	(6.54)c	(9.43)c	
Chlorpyriphos	9.60	5.00	7.40	9.80	22.91	9.40	4.80	7.60	9.40	22.69	9.60	4.20	7.80	10.60	21.52
	(18.02)b	(12.89)b	(15.76)b	(18.23)b		(17.84)b	(12.58)b	(15.99)b	(17.83)b		(18.03)b	(11.77)b	(16.20)b	(18.98)b	
Control	10.40	11.40	12.20	13.40	-	10.40	11.00	12.00	12.80	-	11.40	11.80	12.60	13.80	-
	(18.79)a	(19.72)a	(20.43)a	(21.45)a		(18.80)a	(19.35)a	(20.42)a	(20.19)a		(19.70)a	(20.06)a	(20.75)a	(21.80)a	
S.Em	0.03	0.72	0.04	0.03	-	0.02	0.73	0.05	0.81	-	0.03	0.04	0.02	0.09	-
CD at 0.05	0.756	2.468	1.118	1.161	-	0.913	1.83	2.84	2.36	-	1.56	2.47	3.623	0.79	-

PTC- Pre-treatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are arc sign transformed values in a column means followed by a common letter are not significantly different by DMRT (P=0.05).

C. plutella and *C. carnea* were found safe and number was increased after spraying (Table 6). The phytotoxic symptoms were not noticed after post spraying of tested insecticides under this study (Table 7).

Table 4-6 depicted the economic analysis of IPM strategies in groundnut sucking pests in the years of 2020-21, 2021-22 and 2022-23. The cost incurred on insecticides usage was an essential factor in cost of cultivation. The total cost of IPM based groundnut production was Rs. 77573, Rs. 85068 and Rs. 90021.3 for the years 2020-21, 2021-22 and 2022-23, respectively (Table 8-10) which was than normal farmer practice (Rs. 86085, Rs. 90740 and Rs. 93053). The yield recorded in demo practice was higher (33.18, 30.77, 31.43 q ha^{-1}) with an increased yield of 19.46, 11.36, 12.72% than farmer practice (27.79, 27.64, 28.01 q ha^{-1}) for the years 2020-21, 2021-22 and 2022-23, respectively. The net returns was recorded as Rs. 97441, Rs. 85694 and Rs. 93856 higher in demo than farmer practice (Rs. 60491, Rs. 62673, Rs. 70817) consecutively for the three years. The benefit-cost ratio was calculated and proved that IPM practice in groundnut provided more profit (1.26, 1.01, 1.04) than farmer practice (0.71, 0.69, 0.76) for the three years, respectively. The technology gap in the demonstration was in the range of 0.62-5.44 q/ha over potential yields (Fig 1). Technology gap minimum during the year 2020-21 since more rainfall was received which is responsible for higher yields during 2020 *kharif* season (Supplementary material) and it was correlated with additional net returns achieved during 2020 where 36950.00 rupees was recorded as additional benefit

Table 6: Evaluation of insecticides against natural enemies in ground nut.

Treatments	2020 season				2021 season				2022 season			
	C. carnea		*C. Plutellae*		*C. carnea*		*C. Plutellae*		*C. carnea*		*C. Plutellae*	
	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT	PTC	15 DAT
Flubendiamide	1.6 (1.22)	2.4 (1.54)	1.6 (1.22)	2 (1.37)	1.8 (1.31)	2.2 (1.47)	1.4 (1.14)	2.2 (1.47)	2 (1.56)	2.4 (1.54)	1.6 (1.40)	2.2 (1.63)
Imidacloprid	1.2 (1.08)	1.8 (1.31)	1.8 (1.33)	2 (1.39)	1.6 (1.24)	2.4 (1.54)	1.8 (1.33)	2.4 (1.54)	1.8 (1.44)	2.2 (1.47)	2.2 (1.61)	2.4 (1.69)
Chlorpyriphos	1.4 (1.16)	1.8 (1.33)	1.8 (1.33)	1.8 (1.33)	1.4 (1.16)	1.6 (1.24)	1.4 (1.16)	1.8 (1.33)	1.8 (1.49)	2 (1.37)	2 (1.56)	2 (1.52)
Control	1.6 (1.229)	2 (1.39)	2 (1.39)	2.4 (1.54)	2 (1.39)	2.2 (1.47)	2.2 (1.45)	2.6 (1.60)	1.6 (1.43)	2.2 (1.48)	2.2 (1.63)	2.6 (1.75)
S.Em	0.03	0.04	0.02	0.06	0.03	0.72	0.04	0.086	0.02	0.73	0.05	0.81
CD at 0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

PTC- Pre-treatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are square root transformed values. In a column means followed by a common letter are not significantly different by DMRT (P=0.05).

Table 7: Phytotoxicity parameters of flubendiamide, imidacloprid and chlorpyriphos in ground nut.

2020 season	Leaf tip injury	Wilting	Necrosis	Vien clearing	Epinasty	Hyponasty
			Phytoxicity rating*			
Flubendiamide	0	0	0	0	0	0
Imidacloprid	0	0	0	0	0	0
Chlorpyriphos	0	0	0	0	0	0
Control	0	0	0	0	0	0
2021 season						
Flubendiamide	0	0	0	0	0	0
Imidacloprid	0	0	0	0	0	0
Chlorpyriphos	0	0	0	0	0	0
Control	0	0	0	0	0	0
2022 season						
Flubendiamide	0	0	0	0	0	0
Imidacloprid	0	0	0	0	0	0
Chlorpyriphos	0	0	0	0	0	0
Control	0	0	0	0	0	0

*Observations recorded on 5, 10, 25 and 30 DAT after treatment.

Table 8: Ground nut economic analysis for the year 2020.

Farmer name	Yield (q/ha)		%	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns	B:C ratio	
	Demo	FP	Increase	Demo	FP	Demo	FP	Demo	FP	(Rs ha^{-1})	Demo	FP
K. Dileep	32.56	27.12	20.06	171754	143058	78450	81500	93304	61558	31746	1.19	0.76
M. Srikanth Reddy	33.45	28.15	18.83	176449	148491	76850	80620	99599	67871	31728	1.30	0.84
K. Pavan Kumar	32.56	28.41	14.61	171754	149863	79200	83500	92554	66363	26191	1.17	0.79
P. Vinay Kumar	30.85	27.36	12.76	162734	144324	76800	94500	85934	49824	36110	1.12	0.53
U. Siva Kumar	35.62	29.56	20.50	187896	155929	79300	95630	108596	60299	48297	1.37	0.63
M. Prabhu	34.85	29.78	17.02	183834	157090	78200	86700	105634	70390	35244	1.35	0.81
N. Narayana Reddy	35.74	28.65	24.75	188529	151129	77630	87500	110899	63629	47270	1.43	0.73
A. Soma Sekhar	31.45	25.74	22.18	165899	135779	74500	80500	91399	55279	36120	1.23	0.69
A. Phani Kumar	33.92	26.15	29.71	178928	137941	76300	83600	102628	54341	48287	1.35	0.65
A. Surappa	30.78	26.95	14.21	162365	142161	78500	86800	83865	55361	28503	1.07	0.64
Average	33.18	27.79	19.46	175014	146576	77573	86085	97441	60491	36950	1.26	0.71

Table 9: Ground nut economic analysis for the year 2021.

Farmer name	Yield (q/ha)		%	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns	B:C ratio	
	Demo	FP	Increase	Demo	FP	Demo	FP	Demo	FP	(Rs ha^{-1})	Demo	FP
A. Nagappa	29.56	26.56	11.30	164058	147408	85450	89750	78608	57658	20950	0.92	0.64
P. Suryanarayana	29.8	27.56	8.13	165390	152958	83900	88600	81490	64358	17132	0.97	0.73
M. Manikanta	30.55	27.01	13.11	169553	149906	84500	89650	85053	60256	24797	1.01	0.67
K. Pavan Kumar	31.25	28.17	10.93	173438	156344	85560	91450	87878	64894	22984	1.03	0.71
K. Jayarami Reddy	30.65	28.05	9.27	170108	155678	86950	93600	83158	62078	21080	0.96	0.66
M. Ashok	29.71	26.78	10.94	164891	148629	81470	89600	83421	59029	24392	1.02	0.66
A. Muthyal Rao	32.56	27.56	18.14	180708	152958	86950	93500	93758	59458	34300	1.08	0.64
P. Janaradhan Naidu	32.45	29.86	8.67	180098	165723	87850	92900	92248	72823	19425	1.05	0.78
M. Sukumar	30.92	26.75	15.59	171606	148463	85450	89650	86156	58813	27344	1.01	0.66
P. Ranjith	30.23	28.12	7.50	167777	156066	82600	88700	85177	67366	17811	1.03	0.76
Average	30.77	27.64	11.36	170762	153413	85068	90740	85694	62673	23021	1.01	0.69

Table 10: Ground nut economic analysis for the year 2022.

Farmer name	Yield (q/ha)		%	Total returns (Rs ha^{-1})		Input cost (Rs ha^{-1})		Net returns (Rs ha^{-1})		Additional returns	B:C ratio	
	Demo	FP	Increase	Demo	FP	Demo	FP	Demo	FP	(Rs ha^{-1})	Demo	FP
V. Srinivas Reddy	32.92	29.46	11.74	192582	172341	89003	93750	103579	78591	24988	1.16	0.84
A. Lokanatha Reddy	31.05	28.57	8.68	181643	167135	88575	91880	93068	75255	17813	1.05	0.82
K. Eswaraiah	29.8	27.62	7.89	174330	161577	90235	93450	84095	68127	15968	0.93	0.73
H. Sreeramulu	30.25	27.85	8.62	176963	162923	89900	92980	87063	69943	17120	0.97	0.75
M. Manikanta	31.5	28.63	10.02	184275	167486	91400	94560	92875	72926	19950	1.02	0.77
C. Narasimhulu	30.9	29.56	4.53	180765	172926	92900	94650	87865	78276	9589	0.95	0.83
I. Venkatesh	32.7	28.12	16.29	191295	164502	93500	94550	97795	69952	27843	1.05	0.74
A. Nagaraju	29.8	22.12	34.72	174330	129402	88900	92500	85430	36902	48528	0.96	0.40
A. Sasidhar	33.5	29.45	13.75	195975	172283	87550	90650	108425	81633	26793	1.24	0.90
M. Nallappa	31.9	28.74	11.00	186615	168129	88250	91560	98365	76569	21796	1.11	0.84
Average	31.43	28.01	12.72	183877	163870	90021.3	93053	93856	70817	23039	1.04	0.76

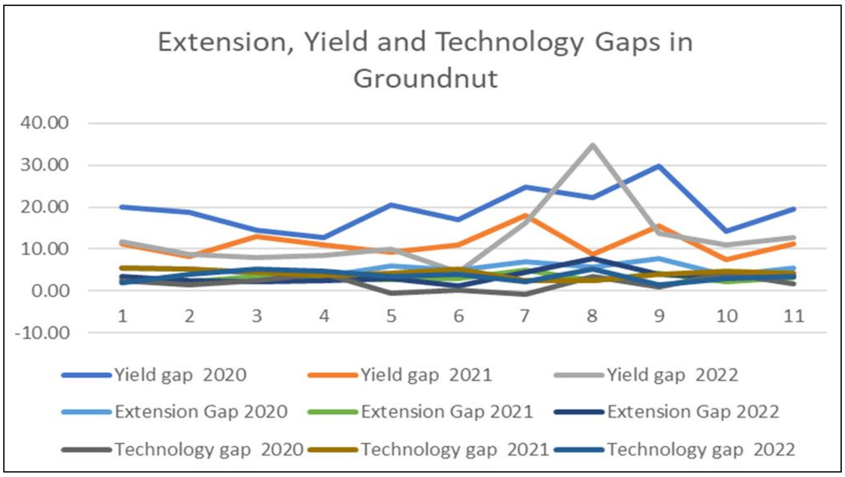

Fig 1: Extension, yield and technological gaps in groundnut.

than 2021 (Rs. 23021.00) and 2022 (Rs. 23039.00). Comparably, over the course of the three years, the extension gap ranged from 1.34 to 7.09 and the yield gap from 4.53 to 34.72.

Application of systemic insecticides such as imidacloprid to control sucking pests before 30 and 45 DAS can contribute to yield improvement as crops escape damage caused by pests during the flowering and blooming stages at 65 DAS without flower drop (personal observation). Due to its knock-down effect and long-term toxicity against sucking pests and its translocation both upward and downwards, imidacloprid was shown to be very effective in reducing groundnut sucking pest populations below the economic injury level (EIL). Neonicotinoids have also been shown to increase crop yield by inducing plant defense mechanisms, which in turn stimulates crop growth under stress (Kumar *et al*., 2023). Similar results were reported by Kandakoor (2012); Roshan *et al.* (2016) and Seetharamu *et al.* (2020) who disclosed that imidacloprid 17.8 SL was effective in reducing of thrips, aphids and leaf hoppers. Imidacloprid is a chloronicotinyl insecticide used to control many sucking insects and acts upon the nicotinic receptors, kills insects by either eliciting a neural toxin response with classic toxicity symptoms (uncoordinated movement and tremoring) or by causing a reversible starvation response (shortened feeding duration, increased test probing and avoidance). Flubendiamide 39.39 SC @ 0.4 mL^{-1} resulted in controlling groundnut *Spodoptera litura* population in all three seasons consecutively and these results are in accordance with results reported by Thakur and Srivastava (2023); Muralikrishna *et al.* (2021); Ahmad *et al.* (2023) and Godoy *et al.* (2023) against leaf eating caterpillar, *Spodoptera litura*. Flubendiamide is having unique mode of action causes multiple disruptions in the target insect's muscle function, resulting in symptoms of poisoning such as rapid feeding cessation, contractile paralysis and regurgitation that ultimately kills the insect. The unique mode of action with greater toxicity for flubendiamide was contributed by its phthaloyl moiety and aliphatic amide moiety along with higher liphophilic nature contributed by aromatic amide moiety (Shah *et al*., 2023).

The current economics of groundnut was similar studies reported by Undhad *et al.* (2019); Marlabeedu *et al.* (2022); Madhusekhar *et al.* (2022) and Sowmya *et al.* (2022). The technology gap (average of all demonstrations for three years 1.82 to 4.23) indicates cooperation of farmers in implementation of critical interventions of IPM at a suitable time may have greater impact on productivity of groundnut. Extension gap ranged from (5.39 to 3.1 q ha^{-1}) proved that efforts of scientists in educating the farmers towards inculcating the knowledge on IPM critical interventions during crop growth period. The lower technological index (5.21 to 10.19%) indicates feasibility of our technology in correlation to net returns and yield of individual farmers.

CONCLUSION

It can be concluded considering into benefit-cost ratios that use of appropriate scientific methods of cultivation especially critical stage application of insecticides before pest status reaching ETL under front line demonstration programme reduced the technological gap to a considerable extent thus leading to increased productivity.

Conflict of interest

The authors have no conflicts of interest to declare that they have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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