



Research Article

# Effect of Insecticide Rotation and Mixtures Use for Resistance Management on Cotton Aphid, *Aphis gossypii* Glover (Hemiptera, Aphididae) in Middle Awash Areas of Ethiopia

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## ABSTRACT

A field experiment was conducted at Werer Agricultural Research Center, Afar region, Ethiopia, to determine the best insecticide rotation sequence and use of compatible mixtures in the Insecticide Resistance Management strategy for cotton aphid, *Aphis gossypii*. Randomized Complete Block design having eight treatment combinations and four replications were used. The parameter assessed were aphid population at pre and post insecticide application; and seed cotton yield. In this experiment, four round of spray application was made by using insecticides from different chemical class and their mixtures. Using the modified Abbott's formula, the percent efficacy was computed. A highly significant difference ( $P < 0.001$ ) was observed among the treatments for post spray counts. In most of the treatments made during the first round spray, the aphid population didn't show a response to the insecticides applied. But starting the second round, the insecticides were able to express their potential in reducing aphid population. In most cases sole treatments were better than mixtures. However, the mixtures like endosulfan + carbosulfan and endosulfan + furathiocarb gave better control of aphid. As the effect of insecticide rotation, treatment 2 (Carbosulfan, Diafenthiuron, Furathiocarb and Deltamethrin), 3 (Dimethoate, Carbosulfan, Deltamethrin and Diafenthiuron) and 5 (Endosulfan, Endosulfan + Carbosulfan, Deltamethrin and Dimethoate) were the best alternative combinations of insecticide groups to be used in IRM strategy. Seed cotton yield was significantly different ( $P < 0.0001$ ) among treatments. The highest seed cotton yield (29.84 q/ha) was recorded from treatment 5 (Endosulfan, Endosulfan\* Carbosulfan, Deltamethrin and Dimethoate), followed by treatment 1 (Endosulfan, Carbosulfan, Deltamethrin and Furathiocarb) and 7 (Furathiocarb Endosulfan \* Furathiocarb, Deltamethrin and Dimethoate) and yielding 26.29 and 20.47 q/ha, respectively. These findings point to the fact that, alternative use of insecticides from different class and using insecticide mixtures is the best option to manage insecticides resistance in cotton aphid.

## INTRODUCTION

Cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) is one of the most important insect pests of cotton in all cotton growing areas of the world. In Ethiopian cotton farms, it takes the second position next to *Helicoverpa armigera* Hubner (Tsedeke, 1982). According to Alemayehu & Ababu (1985) and Tsedeke (1982), cotton aphid causes about 14% seed cotton yield loss in irrigated cotton in Ethiopia. Ripper & George (1965) indicated that, in the Sudan an infestation of approximately 300 aphids per leaf reduce growth by 38 – 44%, boll production by 78 – 80 % and cotton seed yield by 60 – 65 %. If infestation occurs late in the season, the leaves will shade, the boll will open prematurely and the lint will not be fully developed. This is caused through extraction of plant sap and transmission of viral diseases (Pearson & Maxwell, 1958; Ripper & George, 1965). The cotton aphid can transmit several important viruses including cucumber mosaic, onion yellow dwarf, citrus quick decline, lily symptom less diseases and lily rosettes (Blackman & Eastop, 2000). *A. gossypii* feeds by sucking the plant sap (phloem) on the tips of young shoots and under surface of leaves and mostly ant-attended (Pearson & Maxwell, 1958). This feeding depletes the plant nutrients and under heavy infestations leads to distorted and fallen leaves (Dunnam & Clark, 1938).

The other indirect damage which results from the secretion of abundant quantities of honeydew on the plant surfaces, in particular on the open cotton bolls (Shires, 1991; Leclant & Deguine, 1994; Ahmad, et al. 2003). Honeydew is an excellent medium for the various saprophyte fungi which cause sooty moulds, hindering light absorption by chlorophyll and affects plant respiration. In addition, it spoils the seed cotton in open bolls and little drops of honeydew often crystallized and are not eliminated during ginning (Gutknecht, 1988; Leclant & Deguine, 1994), thus lowering market value of the cotton lint (Shires, 1991).

In countries like Iraq, Israel, Turkey, Syria and Romania *A. gossypii*, is considered to be the most serious pest and alone received 80% of insecticide treatments in cotton (Khalid and Al-Zarari, 1983; Ullaha & Paul, 1985 Broza, 1986;). In cotton farms of Ethiopia, broad spectrums of insecticides were widely and indiscriminately used and it is the sole means of cotton aphid management. Despite the wide use of pesticides, there was no strategy designed to manage insecticide resistance. Hence, some of the chemicals like dimethoate, pirimiphos-methyl and phosphamidon have failed to control the insect (Alemayehu & Ababu, 1986).

Moreover, the recently recommended insecticides, carbosulfan and furathiocarb have shown reduced efficacy in controlling cotton aphid in Middle Awash area (Personal communication). This could be due to the development of resistance to these insecticides. Currently, insecticide resistant cotton aphid could be a threat to cotton production in Ethiopia. Hence, designing a possible insecticide resistance management strategy for cotton aphid is very crucial. The two strategies that may delay or mitigate the onset of resistance developing in arthropod pest populations are the use of pesticide mixtures or rotations (Cloyed 2010). This study was conducted with the objective to evaluate the effect of different alternative use insecticide classes and their mixtures on cotton aphid and recommend an optional strategy to mitigate insecticide resistance development.

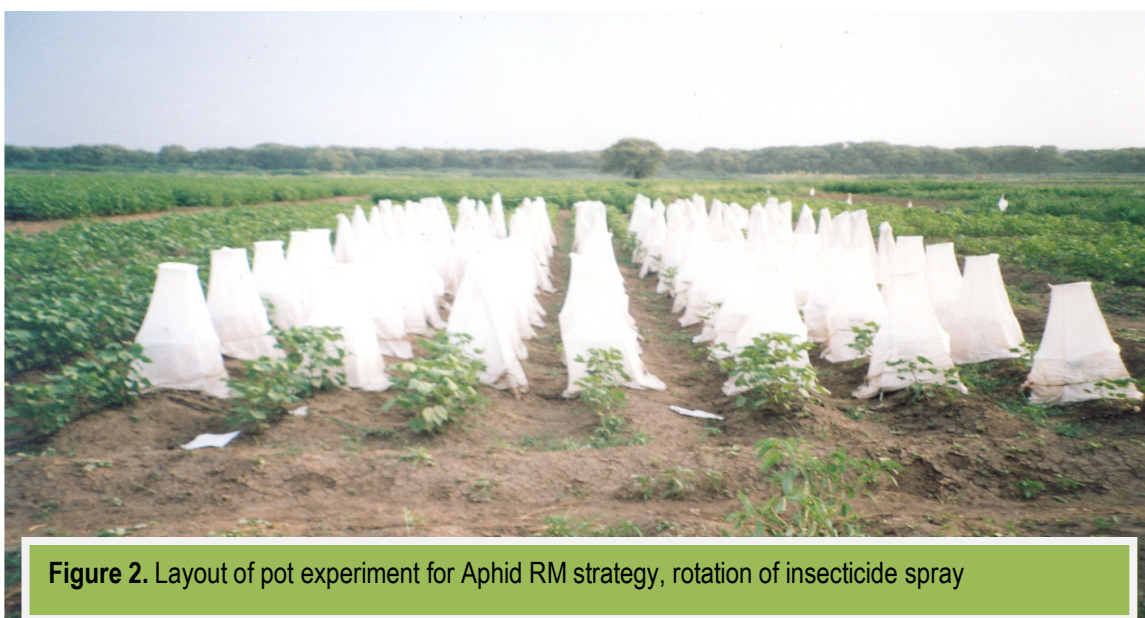
## MATERIALS AND METHOD

### The experimental layout

The on-station experiment was conducted during the main season of 2005/06 cropping season at Werer Agricultural Research Center. The area is situated 280 km to the south east of Addis Ababa at longitude 40°9'E, latitude 9° 60' N and the altitude of 740 m a.s.l in the Middle Awash. The soil type of the study area is chromic vertisol (silty clay to clay) and alluvial (sandy loam to silty loam). The area is under the influence of arid-tropical region receiving mean annual rainfall of 540 mm and the mean maximum and minimum temperatures are 34.4 °C and 19.6 °C, respectively. The insecticides evaluated in this study were from major insecticide classes; carbamates, organophosphates, organochlorins and synthetic pyrethroids, those recommended for the control of cotton aphid and other cotton pests by Melka Werer Agricultural Research Center (EIAR) in Ethiopia. These are Carbosulfan 25% EC, Deltamethrin 2.5% EC, Furathiocarb 200 EC, (Alemayehu & Ababu,1985); Dimethoate 40% EC, Endosulfan 35% EC, (Crow and Shitaye, 1972; IAR, 1969) and Pirimicarb 50% DP (Appendix Table 1). They were obtained from FMC Europe, Brussels, Belgium; Syngenta Agro Service A.G. Ethiopia; Adamitulu Pesticide Processing and Packaging Share Company, Ethiopia; Bayer Crop Science, 6900 LYON, France; and Crop Care. All the insecticides tested were commercial products of Emulsifiable Concentrates (EC) and Dispersible Powder (DP) formulations.



**Figure 1.** Layout of field experiment for Aphid RM strategy, rotation of insecticide spray



**Figure 2.** Layout of pot experiment for Aphid RM strategy, rotation of insecticide spray

The cotton variety Deltapine 90 was used and planted on May 15, 2005 on plots of 54m<sup>2</sup> sizes. The experiment was arranged in completely randomized block design (RCBD) with four replications (Figure 1 & 2). All recommended agronomic practices were followed as per the area. Eight treatments combinations as insecticide class rotation and mixtures application were used. These comprises of seven insecticide applications and one water spray as a control or check. In each treatment group four insecticides were applied in rotational spray order. Treatments were designated by their initial letters and arranged as 1(E C D F), 2(C Dia F D), 3(Di C D Dia), 4(C Lc E D), 5(E E+C D Di), 6(Dia E+ F D Di), 7(F E+F D Di), 8(Uck,Uck,Uck,Uck) (Table 1). Field assessment for aphid infestation was made every week after crop emergence. Counts of aphid colonies (nymphs and alate female) were made on the undersides of leaves, on branches, stems and fruit bracts from ten randomly selected plants in each plot. Insecticide was not applied for any of the cotton pests except for cotton

aphid. However, due to heavy incidence of termite at early stage of the crop development, carbaryl 85% WP was soil applied with irrigation water for all the plots uniformly. The candidate insecticide applications were made when economic threshold level (30% of the plants infested) was attained. The 1st spray application was made on June 22nd 2005 and then, the 2nd, 3rd and 4th round sprays were made on 03/07/2005, 14/07/2005 and 01/08/2005, respectively. Post-spray counts were made at 2, 5, 7 and 10 days after each spray applications. The 10 days after spray application counts were considered as a pre-spray count for their successive sprays.

The pre and post-spray count data were transformed by square-root ( $\sqrt{x+0.5}$ ) transformation. Seed cotton yield and the transformed data were subjected to Analysis of Variance test using the SAS software GLM (SAS Institute, 1999). Combined analysis of the four round sprays was made. When F values were significant ( $P < 0.05$ ), means were compared by Duncan's multiple range tests. Percent efficacy for each

treatment combinations was computed based on the modified Abbotte's formula by Fleming and Retenkarna, (1985).

$$\% \text{ Efficacy} = 1 - \left( \frac{T_a \times C_b \times 100}{T_b \times C_a} \right)$$

Where,

T<sub>a</sub> = Post-spray count in treated plot

T<sub>b</sub> = Pre-spray count in treated plot

C<sub>a</sub> = Post-spray count in check plot

C<sub>b</sub> = Pre-spray count in check plot

**Table 1: Treatment combinations and insecticide groups used for Rotational applications**

No	Treatment combinations	Insecticide groups and their application round			
		1 <sup>st</sup> application (22/06/2005)	2 <sup>nd</sup> application (03/07/2005)	3 <sup>rd</sup> application (14/07/2005)	4 <sup>th</sup> application (01/08/2005)
1	E C D F	Endosulfan	Carbosulfan	Deltamethrin	Furathiocarb
2	C Dia F D	Carbosulfan	Diafenthiuron	Furathiocarb	Deltamethrin
3	Di C D Dia	Dimethoate	Carbosulfan	Deltamethrin	Diafenthiuron
4	C Lc E D	Carbosulfan	Lamdacyhalotrin	Endosulfan	Deltamethrin
5	E <u>E</u> *C D Di	Endosulfan	Endosulfan + Carbosulfan	Deltamethrin	Dimethoate
6	Dia <u>E</u> *Di D C	Diafenthiuron	Endosulfan + Dimethoate	Deltamethrin	Carbosulfan
7	F <u>E</u> *F D Di	Furathiocarb	Endosulfan + Delthanate	Deltamethrin	Dimethoate
8	Uck,Uck,Uck,Uck	Water spray	Water spray	Water spray	Water spray

C= Carbosulfan, D= Deltamethrine, Dia= Diafenthiuron, Di= Dimethoate, E=Endosulfan, F= Furathiocarb, Lc= Lamdacyhalotrin, Uck= Untreated check

## RESULTS

In this study, insecticides from different groups and their mixtures were applied in different sequential orders. During the first round spray, significant variations ( $P < 0.001$ ) were observed among the different insecticides used. However, the insect population was tending to increase and complete controls were not obtained (Table 2). The highest aphid mortality was obtained from furathiocarb and diafenthiuron, 71.9 and 70.4 %, respectively (Table 2).

In the second round spray diafenthiuron, carbosulfan, endosulfan mixed with carbosulfan and endosulfan mixed with furathiocarb have showed 74.6, 73.8, 65.9 and 61.4 percent efficacy, respectively (Table 3). Lamda-cyhalotrin, endosulfan mixed with dimethoate and carbosulfan followed endosulfan treatments resulted poor control of aphid infestation; rather the aphid population was seen to increase in a higher rate ( Table 3). When insecticides are put in order of toxicity level diafenthiuron > carbosulfan > endosulfan + carbosulfan > endosulfan+ furathiocarb; this showed that, sole treatment of diafenthiuron and carbosulfan is better than mixtures. While, endosulfan alone did not control aphid but showed increased level of efficacy when mixed with carbosulfan and furathiocarb. On the contrary, when endosulfan was mixed with dimethoate, it resulted in

resurgence of aphid populations. Therefore, they are not good combinations of mixture to use in insecticide resistance management strategy.

At the third round spray, the synthetic parathyroid deltamethrin was used in most treatments and only treatment 3 and 4 were sprayed with furathiocarb and endosulfan, respectively. All the deltamethrin treated plots had given very low levels of efficacy and this shows that aphid has resulted resistance to this insecticide (Table 4). Similarly, endosulfan also gave low efficacy when sprayed during the third round. On the other hand, furathiocarb was the only treatment, which gave higher level of efficacy (75.67%). Therefore, results confirmed that the use of deltamethrin for cotton aphid management is not effective (Table 4). Due to its continued use for cotton bollworm control, it may have selected some resistant strains of cotton aphid in Ethiopia.

The result of this study showed that, the fourth round is the most effective spray that highly contributed to the combined effect of insecticides in alternate use. Most of the insecticides sprayed at this round were effectively controlled aphid. Carbosulfan, diafenthiuron and dimethoate gave 85.1, 84.5 and 66.8 % mortality, respectively. Furathiocarb gave (62.51%) efficacy only. The efficacy of dimethoate was not consistent among different plots when treated at the same date. Similar to

the previous round applications, the response of aphid to deltamethrin was very low (Table 5).

The result of combined analysis for the rotational spray applications indicated that, there is a significant difference between post-spray counts. The highest mean aphid counts 28.4 and 33.3 were recorded on the untreated check at 7 and 10 days after treatment application, respectively (Table 6). The pooled average post spray count showed that, the highest number of aphids/ leaf (25.6) and lowest (6.3) was recorded on control treatment (water sprayed) and treatment 2 (C Diaf F D), respectively. Similarly, the highest percent efficacy 58.3, 54.7 and 53.3 was obtained from treatment number 2 (C Diaf F D), 3 (Di C D Diaf ) and 7 (F E\*F D Di), respectively. Treatment 5 (rotation of E E\*C D Di), which gave the highest seed cotton yield (2984.4 kg/ha) and showed 50% control.

The main contributors to the combined effect of insecticides were sprayed round two and four. The most effective treatments in round two were diafenthiuron, carbosulfan and carbosulfan + endosulfan. While, during the fourth round furathiocarb, diafenthiuron, carbosulfan and dimethoate were the most effective treatments.

Seed cotton yield showed a highly significant difference ( $P < 0.001$ ) among the treatments (Table 6). The lowest seed cotton yield 4.531 q/ha was obtained from control treatment (treatment 8). On the other hand, the highest seed cotton yield 29.84 q/ha obtained from treatments 5, followed by treatment 1 and 7 (Table 6). The control treatment resulted in very low seed cotton yield and this shows that in addition to qualitative loss aphids could reduce seed cotton yield significantly. Therefore, the estimated seed cotton yield loss from this experiment was about 84.82 %.

**Table 2: Pre and post spray counts of *A. gossypii* and percent mortality with different insecticide classes tested at the 1<sup>st</sup> round rotation application, Werer 2005**

Treatments	Pre-spray	Post spray count ___ DAS				Post spray mean	% Efficacy
		2	5	7	10		
Endosulfan	1.96A	4.45BC	5.38BC	9.47BC	17.63AB	9.23BC	-5.29
Carbosulfan	4.61A	4.97BC	6.69BC	10.62BC	19.53AB	10.45BC	49.32
Dimethoate	4.26A	9.42A	16.38A	20.68A	28.35A	18.71A	1.84
Carbosulfan	2.60A	3.79BC	4.82BC	7.9BC	12.26BC	7.19BC	38.16
Endosulfan	2.89A	4.93BC	7.94BC	13.07AB	21.13AB	11.77B	8.98
Diafenthiuron	1.98A	4.02BC	1.79C	1.97C	2.72C	2.63C	70.36
Furathiocarb	4.20A	1.90C	3.56BC	6.36BC	9.33BC	5.29C	71.86
Untreated check	2.84A	5.77AB	9.08B	14.56AB	21.41AB	12.71AB	-
Mean	3.17	4.91	6.95	10.58	16.54	9.75	
SE	1.62	1.56	2.78	4.02	5.37	3.43	
CV	51.18	31.72	40.01	38.03	32.45	35.55	
LSD	NS	3.69	6.60	9.54	12.73	8.14	

\* Means followed by the same letter within a column are not significantly different from each other at  $P < 0.0001$  (DMRT), DAS= Days after spray, CV= Coefficient of Variability, LSD= Least Significant Difference, NS= None Significant, SE= Standard Error.

**Table 3: Pre and post spray counts of *A. gossypii* and percent mortality with different insecticide classes tested at the 2<sup>nd</sup> round rotation application, Werer, 2005**

Treatments	Pre-spray	Post spray count__ DAS				Post spray Mean	% Efficacy
		2	5	7	10		
Carbosulfan	17.63AB	16.43AB	20.88B	25.35AB	26.68BC	22.34B	20.89
Diafenthiuron	19.65AB	12.07BC	7.02C	6.22C	6.69D	8.00C	74.58
Carbosulfan	28.35A	11.10BC	9.13C	12.17C	15.23CD	11.91C	73.77
Lamda-cyhalotrin	12.26BC	15.42B	26.40AB	26.66A	33.91AB	25.60AB	-30.37
Endosulfan+	21.13AB	12.97BC	9.49C	12.11C	11.62D	11.55C	65.88
Carbosulfan							
Endosulfan+	2.72C	4.13C	8.28C	13.76BC	12.25D	9.61C	-120.50
Dimethoate							
Endosulfan+	9.33BC	3.15C	4.13C	6.96C	8.84D	5.77C	61.38
Furathiocarb							
Untreated check	21.41AB	26.02A	32.51A	37.45A	41.17A	34.29A	
Mean	16.54	12.66	14.73	17.58	19.55	16.13	
SE	5.37	4.27	3.03	5.30	5.99	4.65	
CV	32.45	33.71	20.58	30.12	30.62	28.76	
LSD	12.73	10.12	7.19	12.56	14.20	11.02	

\* Means followed by the same letter within a column are not significantly different from each other at  $P < 0.0001$  (DMRT), DAS= Days After Spray, CV= Coefficient of Variability, LSD= Least Significant Difference, NS= None Significant, SE= Standard Error.

**Table 4: Pre and post spray counts of *A. gossypii* and percent mortality with different insecticide classes tested at the 3<sup>rd</sup> round rotation application, Werer 2005**

Treatments	Pre-spray	Post spray count__ DAS				Post spray Mean	% efficacy
		2	5	7	10		
Deltamethrin	26.68AB	22.55AB	23.74AB	23.72AB	26.95AB	24.24AB	48.96
Furathiocarb	6.69C	2.3D	2.14C	3.71C	3.44D	2.90 D	75.67
Deltamethrin	15.23BC	19.03ABC	16.15ABC	23.0AB	22.8ABC	20.25AB	25.32
Endosulfan	33.91A	27.9A	30.69A	32.94A	35.25A	31.70A	47.49
Deltamethrin	11.62BC	11.61BCD	11.77BC	11.38BC	17.89BC	13.16BC	36.36
Deltamethrin	12.25BC	14.97ABCD	14.89ABC	24.91AB	25.34ABC	20.03B	8.15
Deltamethrin	8.84C	8.11CD	10.49BC	14.37BC	13.96DC	11.73C	25.44
Untreated check	13.26BC	16.23ABC	20.97AB	27.18AB	30.03AB	23.60AB	-
Mean	16.06	15.34	16.35	20.15	21.96	18.45	
SE	6.65	5.53	6.86	6.84	5.37	6.15	
CV	41.44	36.06	41.94	33.97	24.47	34.11	
LSD	15.78	13.11	16.27	16.23	12.74	14.59	

\* Means followed by the same letter within a column are not significantly different from each other at  $P < 0.0001$  (DMRT), DAS= Days After Spray, CV= Coefficient of Variability, LSD= Least Significant Difference, NS= None Significant, SE= Standard Error.

**Table 5: Pre and post spray counts of *A. gossypii* and percent mortality with different insecticide classes tested at the 4<sup>th</sup> round rotation application, Werer 2005**

Treatments	Pre-spray	Post spray count				Post spray Mean	% Efficacy
		2DAS	5 DAS	7 DAS	10 DAS		
Furathiocarb	26.95AB	17.7ABC	16.05B	14.17BC	14.35BC	15.57	62.51
Deltamethrin	3.44D	4.6D	3.93BC	3.16C	3.77CD	3.87	27.08
Diafenthiuron	22.80BC	14.11BCD	3.85C	1.82C	2.02D	5.45	84.49
Deltamethrin	35.25A	28.32A	30.05A	29.31AB	26.06B	28.44	47.65
Dimethoate	17.89BC	15.74BCD	9.52BC	7.36C	7.76CD	10.10	49.90
Carbosulfan	25.34ABC	9.93CD	5.43BC	3.34C	4.58CD	5.82	85.09
Dimethoate	13.96CD	10.39CD	7.71BC	4.74C	5.69CD	7.13	66.84
Untreated check	20.67BC	23.33AB	29.14A	34.52A	40.41A	31.85	
Mean	20.79	15.51	13.21	12.3	13.08	13.53	
SE	4.83	5.18	5.13	6.5	4.96	5.44	
CV	23.24	33.4	38.81	52.86	37.90	40.74	
LSD	11.46	12.29	12.16	15.42	11.76	12.91	

\* Means followed by the same letter within a column are not significantly different from each other at  $P < 0.0001$  (DMRT), DAS= Days after Spray, CV= Coefficient of Variability, LSD= Least Significant Difference, NS= None Significant, SE= Standard Error.

**Table 6: Combined analysis of Pre and post spray counts of *A. gossypii* and percent mortality with different Insecticide classes tested in four rounds of application, Werer 2005**

No.	Treatments	Pre-spray	Post spray count ____ DAS.				Post spray (Mean)	Yield kg/ha	% efficacy
			2	5	7	10			
1	E C D F	18.3ab*	15.28ab	16.51ab	18.18bc	21.40bc	17.84	2628.9 ab	44.64
2	C Dia F D	8.57d	5.98 d	4.94c	5.92d	8.36d	6.30	1851.6 c	58.26
3	Di C D Dia	17.66ac	13.41ac	11.38bc	14.42dc	17.10dc	14.08	1093.8 d	54.74
4	C Lc E D	21.0a	18.86a	22.99a	24.2ab	26.87ab	23.23	2210.9 bc	37.20
5	E E*C D Di	13.38ad	11.31bd	9.68bc	10.98dc	14.60cd	11.64	2984.4 a	50.60
6	Dia E*Di D C	10.57bd	8.26cd	7.60c	11.0dc	12.22d	9.77	2046.9 bc	47.52
7	F E*F D Di	9.08dc	5.88d	6.47c	8.10d	9.45d	7.48	2484 ac	53.26
8	Uck Uck	14.54ad	17.84ab	22.92a	28.43a	33.25a	25.61	453.1 e	
	Mean	14.14	12.10	12.81	15.15	17.78	14.46	1969..38	
	SE	8.04	6.06	6.97	8.25	8.84	7.53	431.73	
	CV	56.89	50.10	54.44	54.47	49.71	52.18	21.923	
	LSD	8.78	8.62	7.61	9.01	9.65	8.72	634.84	

\*Mixtures, \*\* Means followed by the same letter within a column are not significantly different from each other at  $P < 0.0001$  (DMRT), C= Carbosulfan, CV= Coefficient of variability, DAS= Days after Spray, D= Deltamethrine, Dia= Diafenthiuron, Di= Dimethoate, E=Endosulfan, F= Furathiocarb, Lc= Lamdacyhalotrin, LSD=least Significant Difference, SE= Standard Error, Uck= Untreated check

## DISCUSSION

In Ethiopia, a mixture of insecticides were used for cotton pest management (Tsedeke, 1982; Geremew, 2004; Ermias et al, 2008). Even pyrethroids were used early in the season and may result in destruction of natural enemies of cotton aphid. Some small-scale farmers use insecticides from unknown source, usually with reduced dosage and following a wider swathe width, which results in patchy deposition of the treatment (Geremew T and Ermias S, 2006; Ermias et al, 2009). Nowadays, the continued practice of such a misuse of insecticides has resulted in a field failure of insecticides in major cotton growing farms of Ethiopia (Geremew, 2004; Ermias, 2008). Curtis, (1985) has showed that any dose that allows some susceptible to survive will always allow even greater survival of the heterozygote and an increase in the frequency of resistance.

The result of this study shows that, mixtures of carbosulfan with endosulfan and endosulfan with furathiocarb gave 65.88 and 61.38 % efficacy, respectively. Whereas, mixture of endosulfan and dimethoate has resulted in resurgence of aphid populations. On the contrary of this finding, Ahemed et al (1987) reported excellent synergism between endosulfan and dimethoate mixtures for cotton whitefly control. Limited investigations were made in the use of mixtures for the management of cotton insect pests. Ishaaya, (1987) showed a very beneficial improvement (5 to 50x) in the activity of cypermethrin against whiteflies when it was combined with several organophosphates (OPs). UCCE, (1998) recommended the use of tank mixes of provado with endosulfan, metasystox-R, lorsban and ovasyn at different stages of the cotton plant growth to control cotton aphid. A lot of insecticide resistance

## CONCLUSION AND RECOMMENDATION

According to Alemayehu R and Ababu D (1985), dimethoate previously, recorded as non effective now becomes effective for cotton aphid. It is observed that pesticides with reduced efficacy due to serious resistance will regain their efficacy if their use is stopped for 3-5 years. Endosulfan frequently used for bollworm control from long ago and still in use has the potential to suppress the aphid population to lower ETHL. However, its use must be limited to early season cotton pest management. Careful monitoring also needed as it has already developed resistance to some *Helicoverpa* population. To prolong the usefulness of all effective aphicids, IPM practices must be followed by emphasizing on the preservation of indigenous predators, parasitoids and entomophagous in order to regulate aphid population. Avoid indiscriminate and/ or scheduled use of insecticides, which is not only disrupting biological control agents but also needlessly, selecting for resistant aphid. Since, beneficial organisms do not discriminate between susceptible and resistance individuals and so can be useful for cleaning up any

detection studies were made on cotton aphid in overseas. OSU, (1994) and Herron et al. (2001) have suggested use of mixtures and rotation of insecticides as components in Insecticide Resistance Management strategy. Mixing pesticides with different modes of actions may delay resistance development within arthropod pest populations (Ahmad, 2004).

In Australia, cotton producers were able to manage *Heliothis armigera* with the IRM tactics like monitoring, thresholds and area wide compliance (Croft,1990; and Daly & McKenzie,1987). In Ethiopia, field control failure of dimethoate was reported and it was abandoned from use without any research base. Geremew (2005) has clearly demonstrated the significance of rotation and selective use of the most compatible mixtures on African bollworm. Pesticide rotation is a temporal alternation of pesticides with different mode of action and/ or different resistance mechanisms or chemistries (Tabashnik, 1989). The reduced "selection pressure" associated with utilizing pesticides with different mode of action may lead to an increase in the usefulness of effective pesticides (McCord et al, 2002).

The judicious use of pesticides in Ethiopia is increasing in alarming rate and the reason behind this is the expansion of investment in agricultural fields. Currently, the export of high value crops, such as Cotton, Flower cuttings, Pulses, Spices and Oil crops is increasing. As a result, pesticides are being imported without efficacy testing and registration. These may contribute a lot to resistance development in agricultural pests. Therefore, in the future, PRM strategies must be developed and coordinated with IPM.

resistant survivors following a spray. Use mixture of carbosulfan and endosulfan, or furathiocarb and endosulfan when aphid and bollworms complex exists together. Rotate insecticides: Carbosulfan, diafenthiuron, furathiocarb, dimethoate and endosulfan. Deltamethrin is used only when there is heavy infestation of bollworms and restricted to late in the season. Since this is the only study in cotton aphid insecticide resistance detection and management in Ethiopia, there must be a comprehensive and continued work to make generalization. Finally, researches, pesticide users, pesticide companies and policy makers must be concerned and work together in Insecticide Resistance Management to make our environment safe.

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**Appendix Table 1. Lists of insecticides used in the experiments**

Common Name	Trade Name	Chemical Group	Form. <sup>1</sup>	Conc.	Rate/ha (lt/ha)	Supplier Company
Carbosulfan	Marshal	Carbamate	EC	250/lt	1.5-2.0	FMC
Deltamethrin	Decis	Pyrethroid	EC	275 g/lt	0.5-0.6	Aventis
Furathiocarb	Deltanete	Carbamate	EC/ULV	200 g/lt	2.00	Syngenta
Dimethoate	Ethiothoate	Organophosphate	EC	300 g/lt	1 –2	Adamitulu
Endosulfan	Thiodan	Organochlorine	EC	350 g/lt	1.5t	Crop Care
Pirimicarb	Pirimor	Carbamate	DP	500g/kg	1 kg	Crop Care
Diafenthuron	Polo	Theo-Urea	SC	500g/lt	0.8	Syngenta
Lamda-cyhalotrine	Karate	Pyrethroid	ULV	80g/lt	2.0	Zeneca
Water treatment	-	-	-	-	200	-

<sup>1</sup>EC=Emulsifiable concentrât, ULV=Ultra Low Volume, SC= Soluble concentrât, DP= Dispersible Powder