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Acridid pest management in the developing world: a challenge to the rural population, a dilemma to the international community

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Abstract

Acridid pests, locusts and grasshoppers, pose continuing threats to rural communities in developing countries, including sub-Saharan Africa, where human and material resources for controlling these insects are meager to none. The past 15 y have witnessed invasions, upsurges and/or plague of the desert locust, *Schistocerca gregaria*, mixed at times with the migratory locust, *Locusta migratoria migratorioides*, and the Senegalese grasshopper, *Oedaleus senegalensis*—in outbreak and invasion areas in the Sahel, northwestern Africa, the Red Sea region, and southwest Asia. Strained by lack of resources to develop and implement integrated pest management strategies that embrace effective preventive control alternatives, affected countries often resort to spraying enormous quantities of synthetic chemical pesticides to control these pests. During the 2003-05 and 1993-94 upsurges, and the 1986-89 locust/grasshopper plague, close to 25 million liters of pesticides were sprayed, largely with the help of the international community. At current estimates, that may have meant upwards of US$500 million in control cost alone, not to mention associated environment and nontarget costs. This paper attempts an overview of the challenges, impacts, and implications of the current approach, its perceived and actual benefits to rural communities and the dilemma in donors' actions or inactions. It also tries to capture lessons learned and experiences gained from recent and past campaigns and to draw conclusions and offer recommendations for future directions.

Key words

acridid pests, *Schistocerca*, *gregaria*, IPM, preventive control, upsurges, Sahel

Introduction

The desert locust, *Schistocerca gregaria* (Forskål), and other acridid pests, can cause devastation to crops and pasture, so bringing about severe economic distress, food insecurity, social crisis, hunger, starvation, mass migration and the displacement of families, as well as resource-based conflicts (Steedman 1988). Such events were witnessed in Mauritania, Niger, Mali and Senegal during 2003/05.

A story can capture the human misery involved. Here is what Fatouma Diakite of Mali had to say: "When I was a child, my mother used to constantly remind me how bad the desert locust plague could get. One of the stories that she told me many times was that the Dialo family, one of our neighbors, had to give up their children in exchange for a sac of grain. That story really bothered me a lot and made me hate and fear locusts. That is why I want to kill each and every locust that comes in my way".

A plague of *S. gregaria*, mixed with the migratory locust, *Locusta migratoria migratorioides* (Reiche & Fairmaire), as well as the Senegalese grasshopper, *Oedaleus senegalensis* (Krauss), occurred 15 y ago in the Sahel, the Red Sea region, northwest Africa and along the Indo-Pakistan outbreak regions. Some locusts from that plague reached the Caribbean Islands. Five years later, a very serious upsurge started developing in Sahelian West Africa and the Red Sea region, but was stopped by affected countries and regional organizations, with the assistance of the UN Food and Agriculture Organization (FAO) and donors. Table 1 presents historical and recent data on estimated damages and on resources invested in the control of desert locust plagues and upsurges.

For more than a decade since the last upsurge, the desert locust situation remained relatively calm, creating an opportunity for front-line countries, regional organizations and donors to engage in strengthening capacities for prevention and control. Several donors pursued this effort through bilateral and/or multilateral venues. FAO, upon its initiative and with support from international communities, created regional programs (Emergency Prevention System for Animal and Plant Pests and Diseases--EMPRES--being the desert locust component). EMPRES has been operational in the central region for more than a decade, where it has been coordinating activities and programs and strengthening host-country capacity to effectively respond to desert locust problems. The creation of a similar program in the western region was delayed until 2001, largely due to a lack of resources, and it is believed that this contributed to the worsening of the locust situation in this region during the 2003/05 upsurge.

The dismantling of OCLALAV (Organisation Commune de Lutte Antiacridienne et de Lutte Antiaviaire: an organization for the control of locusts and birds in Sahel West Africa) a few years following the end of the 1986-89 locust/grasshopper plague, was seen by some as a contributing factor to the worsening of the desert locust situation in 2003/05 in the region. Although many agree that OCLALAV was technically competent, the recessionary period (absence of major pest activities) that followed the last plague, reduced interest among member countries in financing an organization whose human and material resources "were not fully utilized". This was further compounded by its questionable management. Once, OCLALAV was dissolved, its mandates and resources were transferred to national crop protection departments (CPD) and to migratory pest units, to coordinate responses to locust and bird invasions in their respective countries and across their common borders. With the locust largely in recession for nearly 15 y, the viability of the "new" arrangement went untested until the beginning of the 2003 and 2004 outbreak, when most, if not all, member countries, were found incapable of preventing the ensuing crisis.

Despite the long history of these pests, effective, affordable, safe and sustainable means of controlling them are yet to be widely

Table. 1. Historic data on damage, losses and control efforts attributed to desert locust invasions; data on damage and crop values for the dates prior to 1959 were obtained from Steedman (1988); all other figures are estimated by the author based on available records and from field trips.

Year of Incidence	Country or Region Affected	Level of	
		Damage or loss	Control effort
2003-05	WA, NWA, RS	-	> $260 million
1992-93	WA & EA	-	> $30 million
1985-89	global	-	> $310 million
1958	Ethiopia	167,000 MT of grain*	
1957	Senegal	18,000 MT of grain	
1953	Somalia	$900,000	
1949–57	Morocco	$60 million	
1944	Libya	7 million grapevines**	
1928&29	Kenya	$6.75 million	
1926-34	India	$9 million	

*Enough to feed 1 million people for an entire year; **19% of the country's stock; MT = metric tons; $ = US$; WA = west Africa, NWA = northwest Africa, EA = east Africa, RS = Red Sea.

and adequately available. Synthetic chemical pesticides (SCPs) are effective in killing target pests, but because they are not selective against nontargets, they cannot be called safe. Products, such as biological pesticides (*e.g.*, Green Muscle, a mycopesticide) are only available for limited operations in preventive interventions. Compounded by these constraints, control operations rely on the extensive use of SCPs. During the 2003-2005 and 1993-94 upsurges, and the 1986-89 locust/grasshopper plague overall, close to 25 x 10^6 l of pesticides were sprayed at an estimated cost of >US$500 million, not to mention the environmental cost. Most of this cost was financed by international communities, a problem they have yet to address.

Genesis of the 2003/05 upsurge

Desert locust outbreaks and invasions began building up slowly and gradually in Algeria in the early part of 2003, and continued intensifying in Mauritania, Morocco, Mali, Niger, Senegal, Tunisia and Libya, being further expanded in Saudi Arabia in the central region.

It is difficult to determine the precise location of the genesis of these outbreaks, but surveillance and monitoring in affected countries indicate that the desert locust began breeding simultaneously in the various winter-breeding areas in northern Mauritania, southern Morocco, southern Algeria, northern Mali and Niger, northeastern Sudan and northwestern Saudi Arabia. Here large numbers of adults were seen copulating and laying eggs in the latter part of 2003. Soon, massive numbers of swarms and hopper bands began appearing and increased rapidly.

By late November and December 2003, swarms were reported moving from the primary summer breeding areas in the Sahel into "the winter-spring breeding areas" in northwestern and northern Africa, where abundant vegetation existed over vast areas of recent rainfall.

Here, locusts continued breeding in the spring, and by May 2004 large swarms had begun developing in Morocco, Algeria and elsewhere in the region. By June, large numbers of swarms started migrating back into the Sahel, this continuing well into August. Through late July to September, the Sahel, particularly Mauritania, Mali, Niger and Senegal, were overwhelmed by record numbers of swarms and hopper bands. Locusts reached Cape Verde and the Canary Islands from August on. Some also migrated south into the so-called "southern-circuit"—Gambia, the Guineas and part of Senegal. In October 2004, swarms began leaving the Sahel and heading back to Morocco and Algeria and to some extent, northern Mauritania, where large numbers were seen and treated throughout December and January and parts of February. By late February and early March, swarms had diminished almost everywhere except in a few countries, including Algeria, Egypt and Guinea.

In October and early November, 2004, unusually strong southwesterly winds carried swarms from Algeria into northern Libya and northwestern Egypt. Some of these swarms spread across the Mediterranean Sea and reached Cypress, Jordan, Syria, Lebanon, Israel, Palestine and other countries in the region, but did not develop further. Residual swarms that over-wintered in the highlands of Guinea, began spreading eastwards in the spring of 2005 into southwestern Mali, Burkina Faso and southern Niger. Some of these moved further east into Chad, western Sudan [Darfur[1]] and reached northwestern Ethiopia in July 2005. During this period, swarms settled, bred, and concentrated in a few places along the way.

Despite massive numbers of swarms, despite the outbreaks reaching an upsurge stage, precursor for a plague, they failed to reach full-blown plague—a phenomenon characterized by massive and simultaneous breeding, migrations between and re-invasions of multiple regions, persisting over several seasons. Instead, most swarms that migrated from Sahel West Africa to Morocco, Algeria and other areas in the fall of 2004, encountered massive control operations and cold and dry winter weather that severely curtailed spring breeding in 2005 and broke the cycle of subsequent re-invasions of the Sahel and Red Sea regions. Thus, the situation that reached upsurge, failed to further develop into a full-blown plague. The situation in the eastern outbreak region including, India, Pakistan, Iran and Afghanistan, remained relatively calm, as no major locust breeding took place there.

The last time invasions of this magnitude occurred was during the 1986-89 locust/grasshopper plague, when 29 countries in 3 continents were affected and the invasions lasted more than 2½ y before being contained through massive spray operations and by unusually cold and dry weather in winter-spring breeding areas in northwestern Africa.

Contributing factors to the 2003-05 desert locust outbreaks and upsurge

These desert locust outbreaks and invasions are attributed to a number of factors.

Unusual and favorable meteorological and breeding conditions.—Exceptionally heavy and widespread rains in winter-spring outbreak areas in northwestern and western Africa, that began in June 2003,

[1]Effective survey and control operations were undermined in western and northern Darfur due to the prevailing security restrictions.

[2]*Schouwia purpurea* (Brassicaceae) (Forskål), contains 10 x higher concentrations of thioglucosides than those currently observed in other crucifers (>100 μmoles g^{-1} d.w.)(Mainguet *et al.* 2000). Thioglucosides, when ingested, release products that are usually toxic to generalist insects. The desert locust is a generalist herbivore that, in the Sahara desert, may at times feed only on *S. purpurea*. Long-term exposure to a *Schouwia* diet affected activities of β-glucosidases and β-galactosidases and so growth and assimilation efficiency. The limited adaptation of the desert locust to plant glucosides is compensated for by an ability to tolerate high concentrations of allelochemicals for a short period.

continued well into October in some places, and resulted in abundant vegetation (such as *Schouwia purpurea*[2], *Leptadenia pyrotechnica, Prosopis spp*.) and moist soil in most of the outbreak and invasion areas. This, and the warm temperatures that persisted throughout the breeding seasons, created favorable conditions for locusts to breed and proliferate continuously and invade vast areas.

Remoteness and inaccessibility of the primary locust breeding areas.—Unlike most acridid pests, the desert locust often breeds in undisturbed, remote areas, far from human dwellings. Most of the primary breeding areas are found in low-lying plains, dry river beds (Wadis) or the foothills of mountains such as in the Air and Tamesna Mts in Niger, Adrar des Iforas and Timetrine Mts in Mali and Triz Zemmour and Adrar Mts in Mauritania: all hard to access due to poor infrastructure. Most affected countries in the Sahel were, largely, unable to dispatch survey/monitoring teams in time to better understand the locust situation in their territories. After swarms had reached areas where interventions could be launched, the control units were overwhelmed by the sheer number of locusts. In contrast, Morocco, Algeria, Libya and Tunisia in the western region and Saudi Arabia and Egypt, and to some extent Sudan in the central region, were able to dispatch survey/monitoring teams to the primary breeding areas in time and so averted potential outbreaks.

Lack of well-equipped, well-positioned, and well-coordinated national and regional cross-border surveillance, monitoring and control to contain locusts before spread.— Lack of adequate resources and severe shortages of well-equipped, well-positioned and effective national and regional units, with a mandate to monitor and control transboundary outbreak pests, critically undermined routine local and cross-border surveillance and monitoring in breeding. Coordination and planning of preventive and curative control were also strained. This contributed to the overall worsening of the locust situation in the region and adjacent areas, giving way to unabated, continuous breeding and to a massive aggressive spread of swarms.

Lack of a well-coordinated donor appeal and mobilization plus decreased enthusiasm among traditional donors in responding quickly to appeals.—Locust swarms began appearing in considerable numbers in October 2003 in parts of the Maghreb and Red Sea areas. FAO issued an appeal for US$9 million in February 2004; but there was no response from donors (with the exception of emergency pest operation funds from USAID to FAO's Emergency Operations Division). By April 2004, the appeal had almost doubled and 4 mo later, it escalated to >11 times its original amount.

Despite this early issuance of appeals for assistance, strong regional and/or national coordinating bodies were absent: this did not help stimulate donor response. With several major crises unfolding across the globe, the response of the international community may well be delayed for a problem that has been around for decades with little or no long-lasting solution in place. The 2003/05 upsurge was no exception. For a while, only a few donors were pledging or providing even modest assistance to the affected countries in western and northwestern Africa (Lecoq 2001).

It is often generalized that there is diminished enthusiasm and a reluctance among donor communities to respond to such appeals, until graphic pictures of locusts ravaging crops and pasture reach media outlets. Slow responses and diminished enthusiasm worsened the problem. In reality, without external assistance, most frontline countries remain incapable of tackling problems of this magnitude on their own. This was glaringly evident in Mauritania, Niger, and Mali, where locusts seemed to have taken their course at a critical time due to lack of resources.

Lack of emergency/contingency funds.—The unpredictable nature of desert locust invasions and outbreaks requires rapid access to adequate resources to avert a major crisis. As indicated earlier, without the support of the international community, most affected countries in subSaharan Africa are incapable of stopping locust invasions by themselves.

FAO has a 5-decade-old ministerial mandate to inform, organize and coordinate response actions. However, it does not have sufficient core funds to rapidly mobilize in times of emergency. Some donors, including USAID, have been providing funds through the FAO's emergency operations unit to support emergency pest operations. These funds were among the first external resources available for FAO to access in the early stage of the 2003/05 upsurge. Emergency or contingency funds that can be rapidly accessed to avert such crises can certainly play a critical role. However, currently a lack of sufficient emergency funds constrains FAO from providing timely and effective assistance and responses to affected countries.

Delayed understanding of the biological potential of the outbreaks and invasions originating in the western region.—Normally, desert locust outbreaks in the summer season develop in the central region outbreak areas along both sides of the Red Sea coasts, often referred to as "the epicenter" or "cradle of desert locust outbreaks', and spread further into the western and eastern outbreak regions--in the Sahel and southwest Asia. This created a misconceived expectation that major locust outbreaks will not occur in the western outbreak region and move to the central and northern regions. Somehow this led to a misinterpretation early on that the 2003/04 outbreak would not escalate and reach what eventually it turned out to be.

The 2003/05 campaign operations

Spray operations.—The 2003/05 desert locust control operations began at different times in different areas. In northwestern Africa, in Algeria, it began as early as March 2003, where locusts were controlled in some 740 ha. Until November 2003, operations in this region were only carried out in this country.

In other countries of northwestern Africa, operations began in late November and progressed through early 2005. After a brief pause in August and September, when the large swarms migrated south into the Sahel, the momentum picked up again in October and massive spray operations continued well into December. More than 1 million ha were sprayed each month from October through December 2004, mostly in Morocco and Algeria, where resources were readily available. Close to 5 million ha (>12 million acres) were sprayed in each of Algeria and Morocco between December 2005 and June 2005. Tunisia and Libya reported control operations in April and May 2004 respectively, and treated much less than occurred in Algeria and Morocco (Table 2a)

In Mauritania, Mali and Niger, control operations began as early as October 2003 and progressed through February 2005. During this time, more than 2.58 million ha (>6.45 million acres) were sprayed in the Sahel. It should be noted that the significantly fewer hectares sprayed in Sahelian West African countries, compared to countries in northwest and northern Africa, do not reflect the locust situation in the former region, but rather its lack of resources. This lack undermined the capacity to launch large-scale control intervention. Swarms did not arrive in Senegal, Burkina Faso, Cape Verde or

Table 2a. Area sprayed (x 1000 ha) during the 2003-2005 desert locust campaign in northern, northwestern and Sahelian outbreak regions. Information extracted from 'Areas Sprayed', UN/FAO Desert Locust Bulletins Nos 294-324, March 2003 to September 2005. See References for various situation reports of national locust control services (units, centers, institutes) as applicable in the listed countries.

Month/Year	Northern/north-western countries					Sahelian west African countries				
	Algeria	Morocco	Libya	Tunisia	Monthly total	Mauritania	Senegal	Mali	Niger	Monthly total
3/03	.74				.74					
4/03	.45				.45					
5/03	.34				.34					
6/03	.47				.47					
7/03	.15				.15					
10/3	.47				.47	1.61		.08	.19	1.9
11/3	2.95	8.87	.90		12.75	3.75	.65	12.7	.09	17.19
12/3	1.67	13.7			14.37	1.45		17.4	3.42	22.27
1/04	.59	24.8	.80		26.2	82.9			.01	82.91
2/04	5.57	80.1			85.58	54.5			1.10	55.60
3/04	33.2	447			480.20	24.49			2.93	27.42
4/04	266	347	19.8		367	14.71			1.55	16.26
5/04	494	453	87.7	110	751.14	1.53				13.8
6/04	844	737	59.2		796.9	1.21	.03		.20	1.44
7/04	951	725	3.09		759	5.07	.87		1.08	7.02
8/04	7.0	5.43			12.45	34.64	45.6	16.4	4.40	101.04
9/04	2.8		1.06		3.86	202.1	211	218	98.0	729.01
10/4	132	458	4.93		594.93	458.4	379	107	96.4	1,040
11/4	685	1075	42.7	11.6	1,803.3	312.4	60.5	5.05	10.7	433.2
12/4	441	385	14.1		840.1	59.99	52.5	3.10	2.55	118.13
1/05	288	68.4	.20		356.6		5.91			5.91
2/05	317	6.11			323.11		4.20			4.20
3/05	36.2	.57		.01	36.78		.49			.49
4/05	.55				.55					
5/05	1.6	.047			2.04				.94	.94
6/05	1.2	.006			1.21				.26	.26
7/05	.34				.34					
8/05	.63				.63					
9/05	.32		1.56		1.88				.13	.13
Country Totals	4523	4883	236	121	9862*	1258.7	766	350	206	2581*

*Grand total for each region. The estimated overall total hectares sprayed from March 2003 to September 2005 in all countries was >12.9 million ha (>31.80 million acres): 9.86 million in north and northwestern outbreak areas, 2.58 million in the Sahelian west Africa outbreak region, 68.400 in Sahelian west invasion areas, and 319.400 in the central region outbreak/invasion areas. Cape Verde, Yemen and Ethiopia sprayed 3410, 350, and 172 ha, respectively, and are not included in the columns.

Chad until early July 2004; so substantive control operations only began then, intensifying until February 2005.

In the central region outbreak areas, including Sudan, Saudi Arabia, and Egypt, campaign operations began in November 2003 and continued well into April 2004. During this time, close to 320,000 ha (~790,000 acres) were sprayed against hopper bands and swarms. Most of the spray operations were carried out along the western Red Sea coasts of Saudi Arabia and the eastern Red Sea coasts of Sudan and southern Egypt. Significant locust activities did not occur in the eastern outbreak areas in India, Pakistan, Iran and Afghanistan during the 2003/05 upsurge.

By the end of the 2003/05 campaign, close to 12.9 million ha (>32.76 million acres) had been sprayed in more than 20 countries (Tables 2a & b). The massive spray operations in the Sahel, the Maghreb and the Red Sea regions, contributed significantly to mitigation of the locust swarms that could have developed into a full-blown plague.

Nevertheless, some argue against widespread use of SCPs as costly and unsafe and suggest food assistance as an alternative, much the same way as responses to drought and other natural and man-made disasters are handled (Joffe 1995). Others, crop protection staff, locust experts, development partners, challenge the food assistance approach (FOSAP) as retreating and passive, one that does not take into account the potential long-term effects on rural communities. They perceive food assistance as counter-productive, an approach that ignores the core value of crops, abandons principles of economic growth and development and offers a recipe for dependency. They believe that if locusts were left to take their course, the insects would continue breeding, reach a plague stage, persist for many years, wipe out crops and pasture and severely undermine the future of agriculture and livestock production in affected countries. This situation could continue until these pests were stopped by a harsh climate or other natural disasters.

[1]Except for some funds from USG, Norway and Belgium, nearly all contributions from these donors were received by FAO at least 5 mo after the first appeal in February 2004.

Table 2b. Area sprayed (x 1000 ha) during the 2003-2005 desert locust campaign in Sahelian west African and central outbreak and invasion regions. Information extracted from 'Areas Sprayed'. UN/FAO Desert Locust Bulletins Nos 294-324, March 2003 to September 2005. See References for various situation reports of national locust control services (units, centers, institutes) as applicable in the listed countries.

Month/Year	Sahelian west African [invasion] countries						Central region countries				
	Burkina Faso	Gambia	Guinea	Chad	Guinea Bissau	Monthly total	Egypt	Sudan	Eritrea	Saudi Arabia	Monthly total
3/03											
4/03											
5/03											
6/03											
7/03											
10/03								4.84			4.8
11/03								12.0		3.01	15
12/03							.20	1.84		26.4	28.4
1/04							.61	.54		89.7	90.6
2/04							.01	.31	1.92	24.6	26.8
3/04								.96		2.38	3.3
4/04							.90	.60		1.04	2.5
5/04							2.70	.06			2.8
6/04							.430				.43
7/04							1.43				1.4
8/04							1.67				1.7
9/04						.02	1.79				1.8
10/04	.20					.20					.17
11/04	5.26			6.80		12.56		1.10			1.10
12/04	3.84			2.00		4.45	7.0			.02	7.02
1/05						1,87	43.0	1.32			44.32
2/05		3.29				3.74	47.7	2.61			50.31
3/05			3.90			3.98	1.94	4.87			6.81
4/05		6.03	13.5		7.37	26.9	11.1			2.71	12.81
5/05			6.81			6.81	2.05			5.15	7.2
6/05							.51			.60	1.1
7/05							.56	1.73	8.93		11.2
8/05				6.17		6.17	.05	12.29	11.12		23.5
9/05								.16	.09		.43
Country Total	9.3	9.31	24.21	14.79	7.37	68.4*	112.7	44	22.22	155	319.4*

*Grand total for each region.

Donor and FAO's contributions.—Traditional donors contributed US$ 74.3 million to the 2003/05 campaign through the UN/FAO[1]. FAO also contributed US$ 6.3 million of its own, bringing the total multilateral contributions to US$ 80.6 million (Table 3). Of this, US$ 45.5 million was disbursed with US$ 34.7 million remaining by August 2005. A breakdown of these funds shows that US$ 41.4 million or 51% of the total funds was allocated for pesticides and aircraft hiring (Table 4). Some donors including, USAID, Italy, France, Saudi Arabia, Spain, South Korea, Brazil, *etc.*, also made significant bilateral contributions to affected countries. In addition, the so called "nontraditional donors", including, Morocco, Algeria, Libya and Tunisia, made in-kind and technical contributions to Sahelian countries worth tens of millions of US dollars, which are not included in Table 4 due to lack of accurate figures. Other countries in the Sahel also provided technical and material assistance to their neighbors, near and far. In most cases, it is this kind of assistance that plays a critical role during early stages of the fight against desert locust invasions in many countries.

Impacts on food security and socio-economic welfare of affected populations

The 2003/05 desert locust upsurge caused considerable damage to crops and pasture and undermined the livelihoods of affected communities; but it was difficult to determine the extent of damage. Based on a joint assessment conducted by the UN/FAO, CILSS, FEWS, October/November 2004, a conservative 30% loss was associated with the locust damage and the remaining 70% attributed nationally to drought. However, this figure does not reflect the total loss sustained by a large number of farmers locally in Mauritania, Mali, Niger and elsewhere in the Sahel, where pockets of severe food insecurity were later manifest. The 2003/05 upsurges were also associated with other crises, including mass migrations of farmers and pastoralists to urban areas in search of jobs to support their families, resource-based conflicts among farmers, nomads and pastoralists, scarcity of commodities on the market, offsetting market prices of grains and other produce, and severe food insecurity needing food assistance. With the locust images on newspapers and TV screens, the incumbent governments in most affected-countries had the task of reassuring their people that the

problem was under control. All of these classic events associated with desert locust invasions, happened during the 2003/05 upsurge (FAO 2004, Fews 2004).

An oversimplified theoretical illustration of the potential crop loss from the 2003/05 locust upsurge is provided below, to demonstrate the level of damage that can occur at times like this. The Sahel anticipated ~US$ 2.5 billion in production in the summer of 2004. Using a very conservative damage/loss figure of 10 to 20% of the total production to locusts, this translates into US$250 to US$500 million worth of lost produce. An estimated cost of control for the worst case scenario of treating a staggering 12 million ha in a following control campaign is >US$240 million. A net saving of US$226 million could have been achieved had well-coordinated control interventions been launched in a timely manner to avoid a mere 10% damage. The estimated US$226 million assumes US$24 million in control cost for treating 1.2 million ha or 10% of the 12 million ha that needed spraying and demonstrates the importance of early interventions.

Impacts on the environment

Despite a lack of conclusive data on the environmental impact of the 2003/05 campaign, it is inevitable that spray-operations of such magnitude will have a significant effect. However, this campaign was different from its predecessors in its selection of pesticides, use of new communication and spray-tracking systems, types of aircraft employed, *etc.*, all of which are believed to have had some environmental benefits. In 2003/05, Malathion, Chlorpyrifos, Deltamethrin (pyrethyroid was not used in large quantities due to high cost and inability to withstand the harsh climate) and IGRs (considered relatively safer to vertebrates and adult invertebrates, but not to invertebrates including beneficial arthropods), were used; these contrast with Dieldrin, Lindane, and even DDT which were pesticides of choice in the 1986-89 campaign. Fipronil, a product relatively new to the desert locust ecosystem in the Sahel, was used in 2003/05, but its effects on the environment have yet to be determined. New tracking tools—global and differential positioning systems (GPSs and DGPSs) that greatly improve spray operations, and smaller aircraft with better control—were used during the 2003/05 campaign. Sufficient data are not yet available on usage of GPSs/DGPSs, however, preliminary observations suggest that wherever these systems were employed, environmental risks associated with large-scale spray operations were reduced through precise spraying which minimized the pesticides wasted. Rigorous studies will, certainly, further elaborate the benefits and practicality of these tools in desert locust operations.

Lessons learned

Every desert locust control intervention offers a plethora of lessons that can help improve future planning and operations, and 2003/05 was no exception. Some of the lessons from that campaign are listed below and further discussed in the conclusion and recommendations section.

- Mapping out primary breeding and outbreak areas greatly enhances survey and intervention actions.
- Launching of active cross-border surveillance and the monitoring of joint-control operations, as well as information exchange, are critical for the success of control interventions.
- Supporting and strengthening the capacity of development programs and of activities will help improve effective monitoring and control operations.
- The presence of strong national entities is the first line of offense/defense.
- New technologies, such as the Differential Global Positioning System (DGPS), can improve survey and control operations and offer significant economic and environmental benefits.
- Increased international response is the key ingredient for preventing and controlling the threats of desert locust.
- Participation of nontraditional personnel [military] in joint cross-border operations has proven useful and is worth considering in desert locust operations.
- Rapid access to emergency/contingency funds is critical for a successful and effective preventive/curative control.

Conclusions and recommendations

The remoteness and inaccessibility of the primary breeding areas of the desert locust continue to complicate planning and implementing of effective control operations. Information on meteorological and ecological elements, such as moisture, temperature, wind direction, and vegetation, in breeding and development areas, are critical to effective interventions. Therefore, it is crucial that breeding areas are accurately mapped out, information is acquired on soil moisture, humidity, temperature, wind direction and vegetation in egg laying and hopper/swarm development areas, and then made available for timely control interventions.

The primary responsibility of controlling emergency outbreak pests, also known as "public pests", lies with national governments. Departments of crop protection (DCP), their subunits or migratory pest units (MPU), often housed in a Ministry of Agriculture (MoA) or its equivalents, have the mandate to address this issue. DCPs or MPUs often have the authority to make technical decisions, but not the policy-level management decisions that significantly affect operations. Technical decisions can be of no value unless they are backed by management, which is often hampered by the absence of strong national commitments and strategies, or by a lack of clarity in the strategies. Thus, strong, autonomous, well-equipped and financed, coordinating and operational units, with decision making authority, that can develop and launch IPM-based (Integrated Pest Management) strategies of preventive and curative interventions, should exist in frontline countries. Programs such as EMPRES can make valuable contributions to such efforts and are worth supporting.

Conventional spray-guiding systems often waste pesticides and valuable time and are unsuitable for large-scale operations. New technologies such as DGPS can significantly improve spray operations to within a 10-m correction, and the advanced aircraft-mounted versions offer increased benefits in spray accuracy. Combined with track guidance and data logging, DGPS delivers precision spraying within a 1-m correction. The system automatically records important parameters such as an exact image of the tracks followed by the aircraft and the amount of pesticides used, and helps monitor the entire spray operation. It is suitable for blanket and barrier-spraying. The relatively higher initial cost is offset by significant long-term savings in pesticides, hours of operations and of course, a reduced environmental contamination. Therefore, its use in desert locust operations is worth considering.

The costs of controlling the threat posed by desert locust invasions to food security and livelihood is too high for most affected

Fig. 1. Flooded areas were common in northwest and west Africa and the Sahel (photo: courtesy of CNLAA, Morocco).

to cross-border operations, through a Joint Operation Cell (JOC) that was temporarily created with the help of a Disaster Assistance Response Team (DART) launched by USAID. JOC, composed of the DART, the MoA staff and military personnel from Mauritania and Senegal, organized and launched daily joint survey and aerial-control operations along the borders of the 2 countries for 30 d, and treated close to 383,000 ha before being concluded on November 10, 2004. This approach was later tried by locust experts in the region and assessed as a unique and practical operation worth considering in future programs.

Strategies to address massive, cross-border migrations of desert locust swarms that respect no political boundaries, require strong national and regional monitoring and surveillance, and the JOC approach was found ideal for that. The ability of the JOC partners in bringing together neighboring countries and resources and conducting effective and efficient cross-border operations is an important lesson to learn. Military participation in activities involving pesticides and require special skills and could trigger concern; however, this can be overcome through training. Thus, with adequate planning and supervision, desert locust operations should consider a JOC approach and take full advantage of these,

Fig. 2. The presence of abundant vegetation such as *Schouwia purpurea* (Forskål)(left) and *Leptadenia pyrotechnica* (R) (right) during the 2003/05 upsurge, created favorable conditions for locust breeding (photos by author).

countries to bear. Past and present plague and upsurges have reaffirmed the importance of international assistance, without which the situation deteriorates. There is a general agreement that delayed responses from donors and FAO contributed to spraying close to 12.9 million ha (>32 million acres) against the 2003/05 upsurge, equivalent to treating more than 2 million acres every month for 14 mo! Thus, an early and rapid response by donors, FAO and others will certainly enable affected countries to develop and implement effective interventions and thereby, minimize crop and pasture losses, contribute to the food security and economic well-being of affected communities, and enhance environmental benefits through reduced spray operations.

Overwhelmed by the extent and intensity of locust invasions, a number of countries resorted to involving the military as a partner of a civilian MoA staff in its fight against desert locust invasions. In Senegal, Mali and Mauritania, the military played a pivotal role in coordinating logistics and providing transportation, communication and security support for surveillance and control under the technical leadership of MoA. These partnerships were later extended enormous untapped resources to improve cross-border surveillance, monitoring and information exchange and enhance preventive and curative control interventions.

Rapid access to flexible resources is vital for launching successful desert locust operations. Without such funds, even the best plans and strategies are likely to fail. The responsibility to inform affected countries and the international community on the threat of desert locust, as well as coordination of donor contributions and response, were entrusted to FAO 5 decades ago, but a lack of sufficient and flexible funds often undermined its ability to execute effectively. It is important that affected countries, donors and FAO work together and establish such funds to improve responses to locust threats and thereby contribute to the food security and economic well-being of countries affected by this pest.

Table 3. Multilateral contributions and pledges (in millions of US$) by traditional donors as of September 28, 2005. Some of these countries also provided substantial amounts in bilateral assistance not included here. Information extracted and modified from the UN/FAO Emergency Operations Division, March 2006. See also <http://www.fao.org/ag/locusts/common/ecg/277_en_Funding_Table_cash_received_28sept05.pdf>

Contributor	Amount	Date provided	Beneficiaries
European Commission	30.3	29/09/04	Chad, Mali, Mauritania, Niger, Senegal
		06/10/04	Chad, Mali, Mauritania, Niger, Senegal
France	5.8	16/12/04	Chad
		27/08/04	Morocco, Mali, Mauritania, Senegal
		02/11/04	Mali, Mauritania, Niger, Senegal, Chad
The Netherlands	5.6	29/09/04	Mali, Mauritania, Niger, Senegal, Chad
		12/11/04	Algeria, Morocco, Tunisia
Canada	5.0	21/09/04	Mali, Mauritania, Niger, Senegal, Chad
Italy	4.1	11/10/04	Mauritania
		05/07/04	Morocco
		14/12/04	Niger
		14/12/04	Mali
		14/12/04	Burkina Faso
		22/12/04	Mauritania
		29/08/04	Tunisia
Unites States of America	3.4	15/07/04	Mali
		09/06/05	Chad
		15/06/04	Morocco, Mali, Mauritania, Niger, Senegal, Chad
		15/08/03	Mali, Mauritania, Niger
Saudi Arabia	3.0	01/12/04	Senegal
		26/10/04	Mauritania, Morocco
Japan	3.0	01/10/04	Mali, Mauritania, Chad
United Kingdom	2.7	21/09/04	Mali, Mauritania, Niger, Senegal, Chad
Africa Development Bank	2.0	05/10/04	Algeria, Morocco, Mali, Mauritania, Niger, Senegal, Chad, Tunisia
Int'l Funds of Ag. Development	1.4	04/03/05	Burkina Faso, Algeria, Gambia, Morocco, Mali, Mauritania, Niger, Sudan, Senegal, Chad
		15/06/05	Burkina Faso, Algeria, Gambia, Morocco, Mali, Mauritania, Niger, Sudan, Senegal, Chad
Islamic Development Bank	1.0	03/12/04	Algeria, Libya, Morocco, Mali, Mauritania, Niger, Senegal, Chad, Tunisia
Spain	0.9	27/01/05	Burkina Faso, Cape Verde, Gambia, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, Chad
Sweden	0.9	24/12/04	Mauritania, Senegal
Finland	0.7	28/12/04	Mauritania
Germany	1.2	08/09/05	Mali, Niger, Chad
		15/12/04	Algeria, Mali, Mauritania, Niger, Chad, Senegal
Belgium	0.6	06/06/05	Mauritania
		22/12/04	Morocco, Tunisia
Norway	0.6	05/04/04	Mauritania
		05/08/04	Mali, Mauritania, Niger, Senegal, Chad
Austria	0.5	02/12/04	Senegal
Portugal	0.3	18/04/05	Guinea-Bissau
Intergovernmental Agency for Francophone Countries	0.3	03/12/04	Niger, Senegal
Luxemburg	0.3	27/10/04	Burkina Faso, Mali, Niger, Senegal,
Australia	0.2	25/10/04	Algeria, Libya, Morocco, Mali, Mauritania, Niger, Senegal, Chad, Tunisia
Ireland	0.1	10/08/05	Algeria, Libyan Arab Jamahiriya, Morocco, Mauritania, Tunisia
Greece	0.06	01/02/05	Gambia
UNDP	0.05	20/01/04	Sudan
Czech Republic	0.04	11/11/04	Algeria, Libya, Morocco, Mali, Mauritania, Niger, Senegal, Chad, Tunisia
Total donor funds received	68.5		
Total from FAO	6.3		
Additional donor pledges	5.8		
Grand total	80.6		

Table 4. Resources allocated (x10^3 US$) by FAO for the 2003/05 desert locust campaign, as of 1 August 2005. Information extracted from UN/FAO's Emergency Operations Division, August, 2005.

Input item	Budget allocated	Expenditure to date	Available balance
Pesticides	28,965	18,240	10,725
Sprayers	1,529	1,714	-185
Protective equipment	763	419	344
Communication equipment	1,814	2,081	-267
Vehicles	1,930	1,607	323
Flying hours	12,403	9,666	2,737
Technical assistance	6,824	3,280	3,544
Non-expendable Equipment	3,945	1,581	2,364
Expendable equipment	2,130	1,332	798
General Operating expenses	11,423	4,658	4,658
Support coast	4,852	0	4,852
Total	80.467	45.573	34.894

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