The Practical Implementation of Conservation Agriculture in the Middle East

Stephen Loss[1], Atef Haddad[1], Jack Desbiolles[2], Harun Cicek[1], Yaseen Khalil[3], and Colin Piggin[4]

1 - International Center for Agricultural Research in Dry Areas (ICARDA)
2 - University of South Australia
3 - University of Western Australia
4 - Australian Center for International Agricultural Research (ACIAR)




ICARDA
Science for Better Livelihoods in Dry Areas

Australian Government
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Cover pictures:

Top left – ZT seeder training (Mushagher Jordan).

Bottom left – Inter-row lentil between cereal straw (Tel Hadya Syria).

Top right – ZT planting into cereal residue (Tel Hadya Syria).

Bottom right – Pioneer farmer, Sinan Al-Jalili, discusses point design (Mosul Iraq).

Acknowledgements

We would like to thank the Australian Centre for International Agricultural Research (ACIAR) and Australian Agency for International Development (AusAID) for support through the project CIM/2008/027 which contributed so much to the information in this manual. The outstanding farmers and seeder manufacturers in Syria and Iraq welcomed us into their local communities and taught us much about their farming systems and culture – together we learned how to adapt zero-tillage and conservation agriculture to their conditions. We gratefully acknowledge the support of our collaborating research and extension scientists, private consultants, agricultural companies, non-government organizations, and ICARDA government liaison staff for conducting the extensive participatory extension programs in Iraq and Syria during 2006-14, and we also want to recognize the many technical staff that assisted in the extensive field experimental program in Syria, Iraq and Jordan. Our gratitude also goes to Mr. Sinan Al-Jalili, Iraq, who provided a final edit of this publication. Many of our collaborators are struggling in the difficult current conditions in Syria and Iraq, but nonetheless, are doing a wonderful job in continuing to promote CA in their countries.

LIST OF ACRONYMS

ACIAR:	Australian Centre for International Agricultural Research
AusAID:	Australian Agency for International Development
BOF:	break out force
CA:	conservation agriculture
CT:	conventional tillage
DAP:	diammonium phosphate
DD:	direct drilling
FAO:	Food and Agriculture Organization of the United Nations
F:	natural resistance or force of the soil against the opener
H_{max}:	clearance height or ‘jump height’ of the seeding system
ICARDA:	International Center for Agricultural Research in Dry Areas
$L_{1\%}$:	the distance the seeder needs to travel to seed $100m^2$
MT:	minimum tillage
NT:	no tillage
TSP:	triple superphosphate
ZT:	zero tillage

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Introduction

This publication is designed to help innovative farmers, machinery manufacturers, extension specialists, and researchers learn more about conservation agriculture (CA) in the Middle East, especially the practicalities of implementing the various CA principles in the field. Although CA was little known in the Middle East prior to 2005, it has been increasingly adopted around the world over the past four decades, and has been adapted to almost all crops, soil types, climatic zones, and farming systems.

There is no 'one recipe' for CA that works everywhere - even within the same region, the CA system must be modified to each situation to maximize the efficiency of crop production while arresting soil degradation and maintaining or improving the natural resources of the environment. Also the transition to CA is not easy, especially for small uneducated farmers, and it is important to simplify the technology and minimize the risks of failure during the transition phase. In the Middle East where livestock production is closely integrated into crop production, there are compromises required between the implementation of the CA principles and the realities of livestock production activities, especially the grazing of crop residues. Also, crop rotations are dominated by cereals and it is difficult to promote the benefits of legumes and other rotational crops which are often less profitable in the short-term. These limitations form the basis of a gradual approach to the implementation of a partial or simplified CA system in the Middle East.

This publication relies heavily on knowledge and lessons learnt by a project that was successful in developing and promoting simplified CA systems in the drylands of northern Iraq. The project was funded by the Australian Center for International Agricultural Research (ACIAR) and managed by the International Center for Agricultural Research in Dry Areas (ICARDA) from 2005-2015. As part of the project adaptive research was conducted in Syria, Iraq, and Jordan, as well as southern and western Australia which is directly applicable to other areas of the Middle East and North Africa which experience a Mediterranean environment. In addition to promoting the adoption of simplified CA systems in Iraq, the project had major spill-over benefits in Syria, and strongly influenced CA awareness and development in Jordan, the West Bank Palestine, Turkey, Iran and North Africa where agro-ecological conditions and farming systems are similar.

The project showed that CA, especially the elimination of plowing and the use of zero-tillage (ZT) which in term allowed early sowing, results in immediate and significant cost savings, increases in crop growth and grain yield production, reduced environmental degradation, and over time improved soil quality. In particular, early sowing decreases the risk of crop failure under dry conditions and reduces the negative effects of climate change and variability. Conservation agriculture, even a simplified version for initial adoption, has the potential to produce significant agronomic, economic and environmental benefits, and enable countries to intensify their farming systems in a sustainable manner with major paybacks in terms of greater food security and reduced reliance on food imports.

Figure 1: A farmer with his ZT and conventional barley at Hama Syria (left) and another younger farmer with similar lentil plants from Aleppo Syria (right).

The project realized that the lack of suitable ZT seeders was a major limitation to elimination of plowing and adoption of CA in the Middle East. Australian engineering experts, ICARDA project staff and leading farmers worked with local workshops in Syria, Iraq, Jordan and Iran to produce simple, small and effective ZT seeders at affordable prices for small to medium farmers. The project also conducted participatory extension campaigns in Iraq and Syria to encourage farmers to test ZT seeders and adapt the technology for their own conditions. These activities proved highly successful and the area of ZT adoption reached 15,000 hectares in Iraq in 2014, and 30,000 hectares in Syria in 2012, both from a zero starting point in 2006. There are important lessons that can be learnt for these collaboration and extension efforts.

While there are many advantages with the adoption of CA systems, there are also potential difficulties and limitations that need to be managed. It would be complex and risky to implement all aspects of CA simultaneously in the field, because there is a good chance that one practice may not work correctly and dramatically reduce the overall benefits of CA. After a major initial failure, farmers may not be willing to try CA again. Hence, a step-wise approach to CA is often best, taking into account the realities on the ground and the risks created from the adoption of each change. This applies equally to farmers testing CA systems on farm and scientists working on research stations.

Figure 2: ZT seeder design, operation and performance training in Erbil Iraq, 2012.

We hope this publication will help farmers, researchers, extension specialists, seeder manufacturers and other stakeholders avoid some of the common problems and errors made when implementing CA for the first time, especially within the medium to low rainfall, mixed farming systems of the Middle East and other regions with a Mediterranean-type environment. If mistakes can be avoided, then it is likely that CA proponents will persist in developing a successful CA system that is optimized for their local situation.

You will notice a strong emphasis on ZT seeders in this publication. This is because we believe the elimination of plowing is the most important principle of CA in the Middle East. The ZT seeder is usually the critical starting point when developing a CA system and often holds the key to effective adoption. It has to be well designed for local conditions and operated correctly, otherwise the performance of the whole system will be compromised.

We tried our best to keep the text in this publication to a minimum while retaining sufficient detail to cover the major points, and to include many enlightening pictures and illustrations. This manual is longer than we initially intended, but we hope the users find it worthwhile and that they refer to sections of interest as they need. We sincerely hope that it prompts the readers to learn more about CA in their own individual situation through field testing and further research.

What is conservation agriculture?

Over the past 40-50 years conservation agriculture (CA) has been practiced in various parts of the world, and there are considerable differences in how it is implemented and what it means to farmers and researchers in different regions. According to the Food and Agriculture Organization of the United Nations (FAO), CA is *"an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security, while preserving and enhancing the resource base and the environment"*.

In essence, CA is concerned with **profitable and sustainable agricultural production** – that is, maximizing farm profits in the long-term by optimizing agricultural production while conserving inputs (labor, fuel, seed, fertilizer, pesticides, etc.) and minimizing or mitigating any impacts on natural resources (soil, water and air). In most parts of the world, CA concepts are primarily applied to crop production, but the underlying philosophies can and should also be applied to the whole farming system including animal production, especially where crop and livestock production are highly integrated, as in the Middle East, North Africa, and many parts of Australia.

Three core principles have been generally accepted as defining CA:

1) minimum soil disturbance,
2) permanent soil cover, and
3) diversified crop rotations.

In addition to these three core principles, the successful implementation of CA also depends upon many other good agronomic practices, such as appropriate implementation of time of seeding, seed depth, seed rate, variety selection, nutrient management, and weed, disease and pest management. Let's start by examining each of the three main principles.

2.1 Minimum soil disturbance

The most fundamental principle of CA is minimum soil disturbance, especially in the Middle East. For many centuries, minimum soil disturbance through the use of dibble sticks, hand hoes and small animal-draw cultivators was practiced by ancient cultures in the Middle East where agriculture was first practiced. In this and other parts of the world where agriculture relied on human or animal power, the area of cultivation and level of soil disturbance was restricted. However, with the adoption of tractors and modernization of agriculture in the early 20th century, tillage and the amount of soil disturbance were dramatically increased.

Tillage was used to reduce the population of weeds, diseases, insects and other pests, to prepare a loose, clean and flat soil-bed for the seeding operation, and to conserve soil moisture during fallow periods for following crops. These aims were not always achieved efficiently, and high levels of soil disturbance relying on heavy machinery had many negative impacts, such as the high energy costs, degradation of soil structure including development of hard-pans, reduced water infiltration, and increased risk of soil erosion.

In the USA and Canada, the degradation of soil and declining crop productivity culminated in huge erosion problems during the 'Dust Bowl' era of the 1930s, which encouraged some farmers and agronomists to consider reducing tillage. 'Plowless' farming, strip farming and 'trash-cover' were introduced as early conservation tillage methods to control soil erosion and reverse soil degradation. Seeders that could sow directly into undisturbed soil were developed in the 1940s but the accumulation of crop residues causing blockages, and weed management proved to be a major issues. By 1960s, the development of the broad spectrum herbicide atrazine enabled farmers to plant crops without prior tillage and manage weeds effectively. Later, direct seeding systems were also developed in Australia and South America with the adoption of glyphosate and other herbicides. The other two principles of CA (i.e., soil cover and rotation) were not an important part of these early no-tillage or zero-tillage (ZT) systems.

Minimum soil disturbance and the use of effective ZT seeders is the backbone of CA in most regions of the world, and without this principle it is very difficult to realize the benefits of the second principle, soil cover. Minimum soil disturbance is generally understood as seeding crops into uncultivated land - see section 3.1 for a detailed description of the various levels of soil disturbance, especially as it relates to seed drills.

As in many parts of the world, two or three tillage operations before sowing have been a common part of cropping in the Middle East for many decades (Fig. 3). Elimination of these is a critical part of the low soil disturbance principle in conservation agriculture systems, and this requires a major change in mind-set amongst farmers, extension specialists and researchers.

Figure 3: Moldboard and disc plowing in Syria and Iraq. Two or three tillage operations before sowing, common in the Middle East, create very high soil disturbance.

2.11 Benefits of low soil disturbance

The main drivers of the adoption of low soil disturbance in southern Australia and other parts of the world were:

1) eliminating fuel, machinery and labor costs associated with tillage operations,
2) allowing early sowing,
3) conserving soil moisture in the early part of the growing season through improved rainfall infiltration and reduced evaporation, and,
4) reducing the risk of soil erosion and enhancing soil fertility.

The initial adoption of ZT in Australia in the 1970s and 80s coincided with an increase in the cost of fuel (and other inputs) relative to the price of grain and other products, which forced farmers to become more efficient to remain viable. The elimination of plowing operations not only saved fuel and labor, it also allowed sowing soon after the first autumn rains which boosted water-use efficiency and grain production of cereals and other crops.

Similar benefits have been shown in Syria and Iraq when sowing in late

October or early November before or immediately after first rains, compared to the traditional sowing time of December often four to six weeks after the first rain. This is particularly important under dry and variable seasons, which are expected in increase in the Middle East because the effects of climate change. See section 2.42 for more details on time of sowing.

Plowing promotes the evaporation of water from the soil and reduces valuable moisture for seed germination and crop establishment in the early part of the growing period. While tillage can initially improve water infiltration in degraded soils, it is only a short-term effect - once 10-20mm of rain occurs, the weak structure of the tilled soil often collapses and becomes re-compacted, and its ability to absorb further rain quickly is reduced, causing wasteful surface run-off and increased risk of erosion.

This was illustrated very clearly on a clay-loam soil at an experimental site in South Australia. The field had history of ZT, and this is was the first year of the full tillage treatments in the experiment which had immediate detrimental effects. Following 40mm rainfall 3-4 days after sowing, water accumulated on the soil surface and run-off was seen on cultivated plots, while plots sown with a ZT seeder showed good infiltration of the rainfall (Fig. 4). This rainfall was followed by 15 days of dry weather, causing the soil surface to dry out and a hard crust was formed on the soil surface of the cultivated plots. Consequently, plant emergence was reduced by 20% in the cultivated plots compared to the ZT plots.

Figure 4: An experimental site in South Australia shows poor infiltration on cultivated plots (right) compared to the ZT plots (left) after heavy rainfall, even without residue retention.

Improved infiltration of rainfall into the subsoil and less ponding of water on the surface of undisturbed soils means the topsoil is likely to be less sticky after heavy rain, which can enable earlier sowing compared to tilled soils. Reduced water run-off also means improved storage of water in the subsoil and less risk of water erosion, especially on sloping sites. By not disturbing the soil, the surface area exposed to erosion is minimized, and the improved soil structure makes it more resistant to the erosive forces of water and wind.

Plowing promotes the breakdown of soil organic matter and degrades the soil structure. Heavy tillage work is most commonly associated with mechanical compaction, contributing to the destruction of soil structure. Contrary to traditional thinking, most soils that have not been tilled become soft and friable in the medium to long term when their organic matter content and structure are improved. Old root channels and biopores which are typically destroyed by tillage, remain intact and strengthened in undisturbed soils, and these promote good aeration and infiltration of rainfall, rapid and extensive root growth, and better uptake of moisture and nutrients. Massive cracking, sometimes evident on heavy clay soils with a blocky structure, is also reduced as the soil structure improves.

On some tilled soils, a hard compacted layer, known as a hardpan or plowpan, develops just below the depth of tillage operations (usually 10-15cm), especially with frequent high disturbance plowing when the soil is wet and the use of heavy machinery causing soil compaction. These hardpans suppress root growth and the infiltration of water into the subsoil, increasing the risk of waterlogging and causing inefficient uptake of water and nutrients from the subsoil. Hardpans can be detected manually by inserting a metal rod (5-10mm diameter) into the soil.

In such cases, the growth of some deep-rooted crops (such as radish or canola) can help break up the plowpan layer, but this may take several years. It is often pragmatic to loosen the hard layer with deep tillage and then level the soil surface before ZT is introduced, so that crops can benefit immediately. Once ZT is established within a field any heavy traffic should be kept to a minimum to avoid further compaction, particularly when the soil is wet.

2.2 Soil cover and crop residues

The second principle of CA is the maintenance of adequate soil cover to further minimize the risk of erosion, and reduce evaporation of soil moisture, while increasing soil fertility by increasing the organic matter content and recycling nutrients from crop residues to the soil. Heavy residue retention can also suppress the germination and establishment of some weed species.

In some parts of the world where two or more crops can be growth each year, the production of a cover crop has been advocated to increase soil organic matter and protect the soil during times of the year when the soil is normally fallow, while also diversifying the rotation. This is only possible in high rainfall areas that have an extended growing season or with the use of irrigation. Cover crops cannot be grown over summer in Mediterranean environments without irrigation, and in rainfed areas of the Middle East the only way to protect the soil is by retaining the crop residues (straw and stubble) after harvest.

The crop residues after harvesting the grain includes loose and anchored stubble on the surface (affecting soil cover), as well as below ground root material, an aspect often overlooked in low residue CA systems but significant in its effect on soil improvement and organic matter increase. It has been recommended by several institutions that enough crop residue is retained to cover at least 30% of the soil surface. However, this generic approach is based on soil erosion measurements on sloping ground and the optimum is likely to vary significantly between different locations, regions and production systems.

One of the main challenges of the ZT seeder in CA systems is to be able to sow crops effectively between surface residues without causing problems and leaving most of the residues in place (Fig. 5). This is discussed in detail in section 3.0.

2.21 Benefits of soil cover

Soil cover serves many important purposes. Some of the benefits can be obtained in the short term and others take time to be realized, and many go hand-in-hand with minimal soil disturbance discussed above.

The short-term benefits of soil cover include:

1. reduced wind and water erosion,
2. increased rain water infiltration,
3. reduced evaporation and water loss, and
4. more favorable microclimate for the emerging crops.

Figure 5. The retention of residues from the previous crop over summer and during the early part of the growing period provides many benefits to the soil and crop.

In terms of the micro climate, retained residues not only minimize soil evaporation, they also reduce wind speed at the soil surface especially if the residues are left standing, and lower temperatures due to shading and insulation. While the reduced temperatures are generally an advantage in moderate Mediterranean-type environments, this can be a disadvantage in continental or highland climates where crops are often sown into cold soils which limit emergence and early growth. Deep furrows created by tine-type ZT seeders can also help protect emerging seedlings from wind.

Some of the long-term benefits of soil cover may include:

1. increased organic matter and improved soil structure,
2. protection and enhancement of soil biological activity,
3. increased recycling of nutrients and reduced fertilizer requirement, and
4. suppression of some annual weeds (especially smothering of broad-leaved weeds) and potentially reduced herbicide inputs.

These long-term benefits may take four to five years or more to take effect, depending upon the amount of residue that is retained, the rainfall and the soil type. In dry environments, the amount of biomass produced by crops is relatively low, so even when all of the crop residues are retained, these benefits will take longer compared to more favorable environments where the production of biomass is greater.

2.22 Feeding livestock or the soil?

In the Middle East, the cereal residues after harvest are almost always grazed by sheep and goats because they are valuable stock feed over summer and autumn when limited or no green feed is available (Fig. 6). After grazing, there is often little (if any) crop residue left on the soil surface. Crop producers are often paid for this feed, and in dry seasons the crop residues can be worth more than the harvested grain. In addition many legumes in the Middle East are still manually harvested, whereby all of the plant material (including some of the roots) is removed and used as a nutritious stock feed.

In many regions of the Middle East, livestock owners have the communal right to graze stubbles, even if this is against the wishes of the crop producer, and fencing is not used for field crops with relatively low value. Therefore, it is practically difficult or culturally impossible to protect crop residues in most cases, and the lack of soil cover is usually considered one of the main challenges for the successful implementation of CA in the region.

Figure 6: In the Middle East and other parts of the world, there is a large demand to feed crop residues to livestock, rather than retaining the stubble and straw to benefit soil fertility for following crops.

However, there is an ongoing debate whether stubble grazing in CA systems significantly reduces soil quality and crop productivity. The value of the crop residues for livestock production compared to the benefits in soil fertility and the production of following crops is the topic of ongoing research. Is it better to feed the crop residues to livestock or to 'feed the soil'? Much of the organic matter and nutrients consumed by animals are returned to the soil through their dung and urine, so grazing may not be as detrimental as commonly asserted. This argument is supported by experience in Syria and Iraq where farmers who adopted ZT while heavily grazing their stubbles as per normal, still achieved significant cost savings and increased production, especially when they sowed early.

There is evidence from Australia which shows that crop stubbles can be lightly grazed and provided 1.5 to 2.0 t/ha of residues are retained, this is adequate to protect the soil from erosion and maintain soil fertility. Also, animals grazing cereal residues gain the most nutritive benefit from the initial grazing period, during which they find the fallen grain and any green weeds. Once these are consumed the nutritive value of the remaining stem material becomes minimal. So it can be argued that there is a role for partial grazing to benefit both the livestock and the soil. However, controlled grazing will be difficult to manage in the Middle East without sound fencing, and may not be socially acceptable.

In some cases where livestock pressure is less or non-existent, farmers often burn residues to facilitate tillage and seeding, especially in irrigated areas. This is particularly wasteful because most of the carbon and some other nutrients are lost. Burning of residues should be avoided and ZT seeders with good ability to seed into heavy stubbles used, perhaps along with a residue management operation before sowing e.g. raking or slashing.

2.3 Rotation

Unlike the first two principles of CA which are relatively new technologies, crop rotation has been practiced by farmers around the world for millennia. The first farmers in the Middle East noted that their cereal crops (e.g. wheat, barley and rye) performed better after legume crops (e.g. lentil, chickpea, faba bean or vetch). Much later it was discovered that this is largely because legumes form a special symbiotic relationship with specific bacteria in root nodules which extract (or fix) nitrogen from air, and some of this nitrogen is released into the soil when the legume residues decompose for the benefit of following crops.

Most cropping areas in Middle East are suitable for growing a number of different cereal crops, legumes (many of which originate from this region) and/or horticultural crops. Food legumes such as lentils, chickpeas, faba beans as well as forage legumes such as vetches, grasspea, medics, clovers, can be rotated with cereals such as wheat, barley, and triticale. Forage legumes provide valuable stock feed, either by cutting them to produce hay or silage in spring, or by direct grazing during spring or after maturity. Forage crops not only provide diversity in the rotation, they also reduce the pressure on crop residues for stock feed. Fenugreek (Trigonella), cumin and coriander are other options for rotation with cereals.

Unfortunately, many governments in the Middle East and North Africa promote the growth of wheat over other crops by subsidizing and guaranteeing high wheat prices in an attempt to enhance food security. These policies may reduce the need for wheat imports, but they also promote mono-cropping, and hence, reduce the overall productivity and sustainability of their farming systems. Also crops such as lentil, chickpea and faba bean are usually hand-harvested, and high labor costs make them less attractive economically than wheat.

Much can be done to diversify crop rotations in the Middle East. Taller genotypes together with improved crop management and machinery practices are needed to enable machine harvest of lentil and chickpea. For example, in a lentil-wheat rotation in Syria, sowing lentil between the rows of standing cereal straw from the previous year helped the lentil plants remain erect, increased canopy aeration (reducing disease risk), and assisted machine harvest at maturity (Fig. 7).

Figure 7: A example of wheat:lentil rotation in Syria - ZT lentil was sown between the rows of cereal straw from the previous year (inter-row planting), which helped the lentil remain erect, enabling machine harvest.

Legumes tend to produce lower yields than cereals, but this is often offset by higher prices. The development of higher yielding varieties and enhanced crop management practices will encourage wider adoption. Also a higher level of farm organization and management is required to grow multiple crops simultaneously. The crop and farm management skills of many farmers in the Middle East need to be enhanced.

Cereal-fallow rotations are common in some dry regions of the Middle East. The aim of the fallow practice is to manage winter weeds with tillage and conserve soil moisture, and thereby boost production of the crop in the following winter season. Many farmers believe that soil fertility also benefits from a 'rest from production' in the fallow year. However, several studies in the Middle East and elsewhere have shown that the soil moisture conserved in the fallow year rarely boosts production of the following crop enough to compensate for the lost production in the fallow year. In some cases, farmers use a 'weedy fallow' where the weeds are allowed to grow and are then grazed in spring – this results in even less conservation of soil moisture and smaller benefits. The increases in soil fertility during fallow due to mineralization are typically small, especially in soils low in organic matter.

Instead of using fallow in their rotations, farmers in the Middle East and elsewhere are usually better off planting a crop every year, even if from time to time the crop does not produce a harvestable grain yield. Ideally fallow should be eliminated from rotations, especially the weedy fallow, and replaced with crops such as lentil and chickpea, or forage legumes. When fallow is the only alternative, chemical fallow or heavy grazing during early winter should be used to reduce weeds, rather than tillage.

Some organizations specify that three or more diverse crops are required to satisfy the requirements of a robust crop rotation for CA systems. The evidence for this is limited, and as with the soil cover threshold discussed earlier, the optimum amount of agronomic and economic diversity will vary enormously depending upon the environment, production system, and market prices. It is fair to say that the most common cropping sequence in the low rainfall areas of the Middle East relying solely on cereals (and perhaps fallow) is not sustainable, and greater diversity should be promoted, and greater diversity should be promoted.

2.31 Benefits of crop rotation

As mentioned above, legumes provide a special benefit through nitrogen fixation, thereby reducing the nitrogen fertilizer requirements of following crops. The rotation of crops provides other benefits.

When crop rotation is not practiced, CA and other cropping systems, become vulnerable to a build-up of diseases, weeds and insect pests. By rotating crops, the incidence of these problems can be reduced to minimal levels, especially when other management options (e.g. use of pesticides or tolerant varieties) are implemented. For example, selective herbicides can be used to reduce the populations of broad-leafed weeds in cereal crops, and grass weeds in legume crops. Therefore, the overall population of weeds in the cropping system can be reduced significantly when cereals and legumes are rotated and appropriate herbicides used in each phase.

The other benefit of crop rotation is a result of the diversity of products grown and the subsequent economic resilience. In cases where markets fluctuate widely from time to time, farmers are partially protected from the risk of a crash in the value of their main crop. For example, a farmer only growing wheat might be seriously affected if the wheat price falls dramatically, compared to a farmer that is producing wheat and one or two legumes every year.

This benefit is not so important in countries where farmers are guaranteed a fixed price for their crops by their governments, but in Australia and other countries, farmers experience fluctuations in grain and livestock prices depending on the world and domestic markets. Consequently, the market outlook has a large bearing on the crops planted and the numbers of livestock that are produced on a farm. Farmers benefit from an ability to grow a wide range of crops and animals, and have some flexibility to change the mix of crops and the numbers of livestock in response to relative crop and livestock prices.

2.4 Other crop management practices

As with any cropping innovation, the core principles of CA should be applied with other sound crop management practices to maximize the overall benefits. Good agronomic practices encompass all the crop management operations from seeding to harvest, and attention to detail in all practices is important for successful crop production. Below are some important other management practices that will enable CA systems to achieve their maximum potential. Weed, disease and pest management are especially important under ZT and this is discussed separately in section 4.0.

2.41 Variety selection

There is evidence in the scientific literature that some varieties may perform better under CA than conventional systems and that new varieties may need to be bred specifically for the new cropping system. However, preliminary work in Syria testing different wheat, barley, lentil and chickpea varieties found no differences between their performances under the two cropping systems – varieties that were high yielding under conventional system were also high yielding under CA, and vice versa.

Theoretically, varieties selected under CA could have different traits that make them specifically adapted to CA systems, compared to varieties selected under conventional conditions. For instance, cereals with longer and thicker coleoptiles (the protective sheath covering the shoot emerging from the seed) may be better able to emerge through tough soils and thick crop residues. However, such varieties specifically adapted to CA systems have not yet been developed.

Most crops are especially sensitive to frost damage at the flowering stage which can cause massive reductions in yields. For example, wheat planted in early October may flower in early April when the risk of frost is still high in some areas of the Middle East. With very early sowing (see 2.42 below), varieties with longer durations between emergence and flowering may be required in such cases. In frost prone areas of Australia, farmers

keep seed of two or three varieties of wheat with varying flowering times, so that the risk of frost damage can managed if there is an opportunity to sow very early. However, late flowering varieties sown at the conventional time or later are often exposed to heat and/or drought stresses in late April and early May. For late sowings, short duration varieties are best. In Mediterranean-type environments there is often a trade-off between frost damage if flowering is too early, and heat and/or drought stress if flowering is too late.

Recommendation: Based on the limited results from Syria, we recommend that farmers use the same best available varieties for conventional and CA systems, even though they may not have been developed specifically for CA.

2.42 Time of seeding

Many crops in the Middle East region are traditionally seeded during December. Farmers usually wait for the first rains in autumn to germinate the weeds, and then cultivate several times to kill the weeds and prepare a suitable soil tilth before sowing commences. Late arrival of the rains may significantly delay sowing under such a strategy and sowing in January is occasionally required.

A number of experiments and farmer experiences around the world in areas which have a Mediterranean-type environment, including the Middle East, have shown that early seeded crops have greater water-use efficiencies and grain yields compared to crops where sowing is delayed, especially in areas with less than 450mm rainfall p.a. (Fig. 8). This is because early sown crops are able to make use of the first rains and establish rapidly under warmer temperatures in autumn. Also, compared to late sown crops, early sown crops fill grain earlier in spring when temperatures are likely to be cooler and more soil moisture is available. On average, early sown crops avoid heat stress and moisture deficits in early summer. See comments on frost risk in 2.4

Figure 8. Mr. Hussin Al-Deghim shows the difference in barley growth between his late sown field after conventional tillage (left), and early sown field using ZT (right), just before harvest at Jarjanaz, Syria.

In southern Australia, the yield benefit of early sowing is between 15-35 kg/ha for every day seeding is advanced, or up to 250 kg/ha for each week earlier the crop is sown. The opportunity to sow crops early was a major incentive for Australian farmers to eliminate tillage operations and develop direct seeding or ZT systems. Under ZT, crops in the Middle East can also be seeded immediately after the season's first rains in October or November. Sowing before the rain into dry soil is also possible before weeds have a chance to germinate, and this has been used successfully by farmers in Syria and Iraq.

As in Australia, early seeding is one of the key benefits of ZT in the Middle East. In a long-term experiment in northern Syria, zero-tillage which enabled early sowing increased the yield of wheat, barley, lentil and chickpea by 12-20% on average, compared to the traditional practice of late sowing after conventional tillage (Fig. 9).

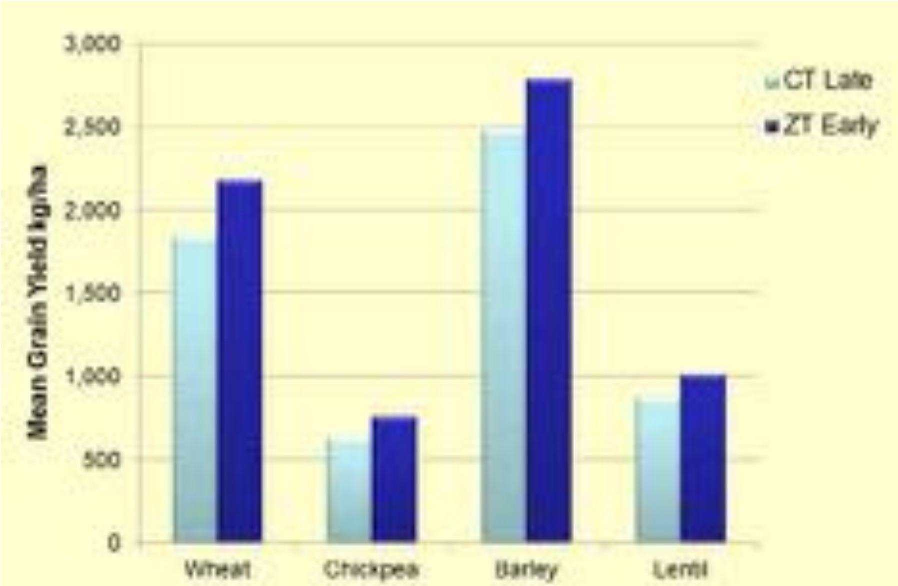

Figure 9: The mean yields of four crops sown early using zero-tillage (ZT Early) and those sown 4-6 weeks later with conventional tillage (CT Late) over four years in northern Syria.

The benefits of early sowing are not as great in legumes, compared to cereals. In particular chickpea is prone to cold temperatures in winter which reduces pod-set and may also increase the risk of foliar diseases like Ascochyta Blight. In very cold areas chickpea is often sown in spring to avoid these issues. Farmers should start their sowing program with cereal crops before moving on to legumes, leaving chickpea to last.

In regions with more than 450mm rainfall p.a. water is not such an important limitation and the benefits of early sowing are not as great in as drier areas. In some areas there is sometimes late summer rain which promotes early weed growth. If farmers are using ZT and are not ready to plant crops, there is an opportunity to graze these weedy fields immediately before sowing at a time when animal feed is usually in short supply and shepherds have to rely heavily on supplementary feeds, usually barley. Under the traditional CT system, this growth is often plowed into the soil and grazing is not possible.

Recommendation: In medium and low rainfall areas, sowing cereal crops as early as possible, either immediately after the first effective autumn rains, or even into dry soil before the first rains, maximizes their water-use efficiency and grain yields in the long term.

2.43 Seeding depth

In the Middle East, some farmers still plant their crops by hand-broadcasting seeds onto cultivated or ridged soil (Fig. 10), and then cover the seeds by cultivating again or splitting the ridges. This practice, known as 'broadcast over ridges', causes variable placement of seeds. Some seeds are placed so deep that they do not emerge at all, or expend too much energy emerging from depth, while others on or close to the soil surface are exposed to dry conditions and predation by birds and other pests.

Figure 10. Spreading seed by hand followed by mechanical incorporation is still used in parts of the Middle East.

Even when seed drills are used to plant crops, many farmers do not pay enough attention to the calibration and operation of the drill to achieve uniform and optimum seeding depth on all seed rows across the whole field. See sections 3.6 and 3.7 for details of seeder calibration and operation.

In the case of sowing into dry soil before the first effective rains, relatively deep sowing at 5-8 cm is recommended, as this will help prevent partial seed germination if light early rains occur. Some cereal varieties have long coleoptiles and are better able to emerge from depth than others. For chickpea and lentil, the optimum sowing depth is similar to cereals, but in general large-seeded legumes are better able to emerge from deeper sowing.

Recommendation: In general, the optimal seeding depth for cereals is between 4 to 6 cm, depending on the region, soil type and soil moisture conditions at planting.

Figure 11. Seed depth needs to checked and adjusted carefully in each field before commencing sowing.

2.44 Seed rate

To compensate for high seed losses due to variable seed depth and poor quality seed, Middle Eastern farmers typically use high seed rates. For cereals, 150 to 250 kg/ha is common. Farmers in this region like to see a thick crop after emergence (more than 300 plants/m^2). However, this causes excessive competition between plants for moisture (especially under dry conditions), nutrients and light, and ultimately reduces grain yield.

Experiments in Syria, Iraq and Jordan show that the optimal seeding rates for most cereals are in the range of 70 to 100 kg/ha targeting 150-

200 plants/m², when sown carefully with ZT seeders and using quality seed with a high germination rate (more than 95%). For lentil and chickpea, 100-120 kg/ha is recommended. In countries where price of seed is high, reduced seed rates can represent a significant cost saving in CT and ZT systems alike. When increasing seed of new varieties, the recommended seed rates should be reduced by 30-50% to maximize the number of seeds produced per plant and the overall multiplication rate.

Some farmers wrongly believe that under CA, higher inputs of seed are required to achieve the higher yield potential. High seed rates are wasteful and detrimental to yield, especially under dry conditions, and reducing seed rates can represent a significant cost saving.

Recommendation: We suggest seed rates of 70 to 100 kg/ha for cereals and 100-120 kg/ha for lentil and chickpea, depending upon the mean seed weight and viability.

Figure 12. Mr. Waad Ahmed inspects the establishment of his wheat crop sown at 90kg/ha on 30cm row spacings, near Mosul Iraq.

2.45 Nutrient management

Soils in the Middle East were once relatively fertile. However, deficiencies of phosphorus and nitrogen are now widespread after many centuries of crop production and export of nutrients in grain, in combination with soil erosion. Fertilizers are somewhat expensive, but in most cases they are important inputs which allow the crop to achieve its potential, especially if the yield potential is increased with CA and early sowing. Plants suffering from nutrient efficiencies suffer from low water-use efficiency and can be more susceptible to weeds, diseases and insects.

Good nutrient management practices should be followed under CA where high biomass production and inputs of organic matter to the soil are desirable. As with all inputs, it is important to maximize the benefits produced by each fertilizer application, and eliminate unnecessary applications which do not increase yields and provide a good economic return. While there may be greater recycling of nutrients in CA systems where crop residues are retained, these are likely to be small, and only slight changes to nutrient management are probably required.

Soil testing by a reliable laboratory is the best way to determine if phosphorus is likely to be limiting, and how much should be applied as fertilizer, either diammonium phosphate (DAP) for cereals, or triple superphosphate (TSP) for legumes. Pre-seeding fertilizer is traditionally broadcast and incorporated into the soil by tillage operations in the Middle East. This results in low nutrient availability and poor uptake by the crop. When phosphorus fertilizer is placed in furrows near the seed with modern seed drills, it is immediately available to the seedlings, and rates can be reduced compared to traditional application methods - see 3.35 for more machinery details.

The crop's requirement for nitrogen fertilizer (urea, ammonium sulphate, or ammonium nitrate) will depend upon the crop rotation and its yield potential. As mentioned previously, cereals following legumes will have a lower nitrogen requirement than cereals following a non-legume. Provided legumes are well nodulated, they do not require nitrogen fertilizer.

Because of the lack of legumes in the rotation, many cereal crops in the Middle East benefit from the application of nitrogen fertilizer, especially if the rainfall is above average. Nitrogen is normally broadcast to cereal crops during the early to late tillering stage of development, provided crop establishment, weed populations, rainfall and seasonal conditions are favorable and average to high yields are expected (Fig. 13). If growing conditions are not promising and the yield outlook is low, then the application of nitrogen fertilizer may not produce a yield benefit which covers the cost of the fertilizer, resulting in an economic loss.

Recommendation: Experience with ZT cereals in Syria suggests 150 kg/ha DAP be applied if the soil P level is less than 5 ppm, 100 kg/ha DAP for 5-10 ppm, and 50 kg/ha DAP for 10-15 ppm. No P fertilizer is required if the soil P level is above 15 ppm. The same rates of TSP can be used for legumes.

Figure 13. Nitrogen fertilizer can be top-dressed at the mid to late tillering stage of the crop, if yield potential looks promising.

2.5 Overall benefits of conservation agriculture

When all the principles of CA are combined along with the other good agronomic practices, many significant benefits are produced. Technologies that benefit the environment can often have a negative effect on crop productivity and short-term profitability. However, CA is one of few practices which can enhance yield, economic returns, and food security while conserving or improving the natural resources. It benefits the farmer as an individual and the wider community simultaneously. In addition, CA is an important way of coping with climate change and increasingly variable seasons, especially in the Middle East.

The benefits of CA can be broadly characterized into three broad categories: production, environmental, and economic.

2.51 Production

Productivity increases are common in well managed CA systems. These may take several years to develop, because some of the improvements in soil fertility are long term, and farmers may need to become familiar with new crop management practices while adapting the CA system to their individual farming operations over a period of the first two or three years, or possibly more. As mentioned previously, yield increases of 12-20% were measured in wheat, barley, lentil and chickpea, when all principles of CA were employed along with early sowing in experiments in Syria over four years. A key step in achieving grain yield improvement is the successful establishment of the ZT crop.

A comprehensive survey was conducted in 2011of 820 farmers in Syria and Iraq, 320 who had adopted ZT and early sowing. The average wheat yields of farmer who used ZT and early sowing were 160-495 kg/ha greater than farmers using conventional tillage and sowing times. Interestingly, yield increases were evident in both dry and favorable seasons, and in fields where supplemental irrigation was used and wheat yields were above 4.0t/ha.

Most importantly, in dry years when nearby conventional cereal crops failed completely, many farmers using ZT and early sowing were able to harvest 500-1,000 kg/ha. These yield increases can be attributed to increased rainfall infiltration (reduced run-off), moisture conservation over summer and during the growing season, enhanced water-use efficiency of the early sown crops, and improved soil structure and fertility. So CA helped avoid the effects of drought and enabled crops to produce useful yields even in the driest conditions.

Figure 14: Among the first farmers to adopt ZT in Syria, Mr. Ali Elewi from Qamishley was impressed with cost savings and yield advantages.

2.52 Environmental

The adoption of CA can help improve the quality of soils, water systems, and air. Reduced soil erosion due to less exposure to both water runoff and wind, is a major benefit of the low soil disturbance and soil cover principles of CA. Dust storms are common in the Middle East each autumn, and the resulting soil erosion, particularly the loss of the fertile topsoil which contains most of the nutrients and organic matter, causes major degradation and reduction in soil fertility.

This has a direct impact on the individual farmer and the widespread community as a whole who must manage these dust storms, especially the detrimental health effects. As less land is plowed and more soil is covered with residues, the severity of these dust storms will decline.

Improvements in soil fertility, especially soil structure and cycling of nutrients through the use of legumes, can reduce the need for fertilizer applications, and reductions in weeds, diseases and pests may decrease the reliance on pesticides.

There has been much speculation about the ability of CA to increase soil organic matter, sequester carbon and possibly mitigate the effects of carbon dioxide emissions and greenhouse gas effects. Some of these claims are somewhat exaggerated. Certainly, ZT can reduce the use of fossil fuels and greenhouse gas emissions associated with agricultural production in some cases.

Increases in soil carbon under CA are common, however they are likely to be small in low rainfall areas. After six years of CA experiments in Syria, the carbon sequestration rate measured was in the range of 0.27 to 0.30 Mg C/ha/year, and this rather modest increase was probably due to low to moderate crop productivity and a reasonable starting soil organic matter content of about 1.3 percent.

2.53 Economic

The elimination of plowing costs, along with reductions in seed inputs decreases the cost of crop production. Even without any increase in production (which is sometimes the case), CA usually reduces costs and thereby increases profits. But when combined with the production increases discussed above, the net economic effect is significant.

In surveys of Syrian and Iraqi wheat farmers who had adopted ZT and early sowing, the estimated reduction in production costs was around $US 100/ha, and their net incomes were boosted by $US 187/ha, on average. If 80% of wheat farmers in Syria used ZT (the typical levels of adoption in many parts of Australia) this would produce an extra 630,000 tonnes of wheat worth about $US 254 million per year. Of course other crops will also benefit from CA. Similarly, CA could have a major impact on the economic productivity and food security of many countries across the Middle East and North Africa, reducing their reliance on imports to feed their populations.

2.6 CA adoption around the world

Conservation agriculture (more precisely, ZT plus one or both other principles) are practiced on more than 125 million ha in all continents and all agricultural ecologies around the globe (Table 1). Zero-tillage is now being practiced from sea level to 3,000 m altitude and from extremely rainy areas with 2,500 mm a year to very dry conditions with only 250 mm a year on average. In 1973/74 CA systems covered only 2.8 million ha worldwide, but the area grew rapidly over the next 30 years, and in the last 11 years, CA systems have expanded at an average rate of more than 7 million ha per year.

Huge areas have been adopted in North and South America, Australia, Russia and China. In eastern and southern Africa, small landholders have adopted CA techniques using ZT seeding equipment suitable for hand sowing or small animal-drawn seeders. ZT seeders have also been adapted for small two wheel tractors in Bangladesh and elsewhere. The key message is that CA can be made to work in all areas of the world where crops are grown, and in almost all crops.

A most relevant example for the Middle East is the experience in Western Australian, where 86% of the farmers are practicing CA with early sowing under dry and variable seasons with 250-350 mm rainfall a year, and are achieving high water-use efficiencies. Although the agro-ecologies of the two regions are similar, free roaming livestock on almost all croplands in the Middle East make it difficult to retain crop residues. Furthermore, unlike southern Australia where highly-mechanized, large farms dominate, most Middle Eastern farmers are relatively small and resource poor. In a survey of Syrian cropping farmers, 20% had farms less than 5ha, while the average size of the large farmers was 26ha. Interestingly, all farmers had access to 70 Hp tractors. In a similar survey in Ninevah Iraq, farm size of small and large farmers combined was 69ha.

Table 1. Adoption of conservation agriculture worldwide (Friedrich et al., 2012).

Country	CA area (ha)	Country	CA area (ha)
USA	26,500,000	South Africa	368,000
Argentina	25,553,000	Venezuela	300,000
Brazil	25,502,000	France	200,000
Australia	17,000,000	Zambia	200,000
Canada	13,481,000	Chile	180,000
Russia	4,500,000	New Zealand	162,000
China	3,100,000	Finland	160,000
Paraguay	2,400,000	Mozambique	152,000
Kazakhstan	1,600,000	United Kingdom	150,000
Bolivia	706,000	Zimbabwe	139,300
Uruguay	655,100	Colombia	127,000
Spain	650,000	Others	409,440
Ukraine	600,000	*Total*	*124,794,840*

2.61 CA in the Middle East

Conservation agriculture was first introduced to Middle Eastern farmers in a coordinated way by a project funded by the Australian Center for International Agricultural Research and managed by ICARDA from 2005-2015. Prior to this project, CA was little known or tested in the Middle East.

The project conducted numerous adaptive experiments in Iraq and Syria, from which a conservation cropping package was developed (Table 2). Australian machinery expertise was used to enhance the knowledge and skills of workshops, and increase the availability of ZT seeder suitable for small to medium farmers in the region. By the end of the project eight manufacturers in Syria, two in Iraq, one in Jordan and others in Iran were producing simple and affordable ZT seeders ranging from 2-4m in width costing US$4,000 to 12,000.

With the availability of these seeders, participatory farmer groups were established to test the conservation cropping package on farm in Syria and Iraq.

The project leaders deliberately took a flexible participatory approach to promoting CA, letting farmers decide which practices they wanted to evaluate and adopt. The project leaders viewed adoption as a gradual process, and did not push all elements of CA simultaneously as this would have been too many changes for most farmers to agree to and manage successfully. With multiple changes the risk of one element going wrong would have been very high, leading to a negative experience and dis-adoption. A priority was given to ZT as this provided immediate savings, and when combined with early sowing, production increases were also likely.

In the vast majority of cases, farmers in Syria and Iraq initially adopted ZT and early sowing, and did not change stubble grazing or crop rotation practices. The cost savings and production increases of these technologies were discussed in the previous section. Remarkably, very few farmers experienced a yield reduction when testing ZT, even though it was the first time they had tried the technology.

Table 2: The recommended 'conservation cropping package' (with key elements in bold) derived from field experiments and on-farm demonstrations conducted in Syria and Iraq from 2005-2014.

Stop plowing
Keep crop residue on the soil surface if possible - don't burn stubbles
Graze stubble if unavoidable
If needed, kill weeds at sowing with a non-selective herbicide like glyphosate
Plant early before the autumn rains (October) or immediately after (November)
Use ZT seeders for all crops
Use good quality seed of the best adapted varieties
Reduce seed rates: 70-100 kg/ha cereals; 100-120 kg/ha pulses
Sow consistently at a depth of 4-6cm for cereals
Use best fertility and weed/disease/pest management practices
Include non-cereals in rotations if possible

In 2014 the area of ZT in Iraq was around 15,000 ha, while in 2012 in Syria (the last available reliable figures) the area of ZT was around 30,000 ha. Sadly, civil unrest seriously disrupted adoption in both countries. In addition to promoting adoption in Iraq and Syria, the project strongly influencing CA awareness and evaluation in Turkey, Lebanon, Jordan, Iran, the West Bank Palestine and North Africa. The successful of the ACIAR funded Iraq project along with the constraints and future prospects for the adoption and promotion of CA in the Middle East is further discussed in section 6.

Figure 15. Mr. Salam Ibrahim, Directorate of Agriculture, and a farmer inspect the grain produced from ZT crop under irrigation in Al Baghdadi Iraq.

The view of CA in many organizations around the world is that all three principles of CA are equally important, and these act as universal ‘pillars’ which support a range of benefits, ultimately leading to greater long-term profits in all parts of the world (Fig. 16). Without all three pillars, the cropping system becomes unstable and many not work effectively. These organizations are sometimes critical of farmers who choose not to adopt all three principles simultaneously.

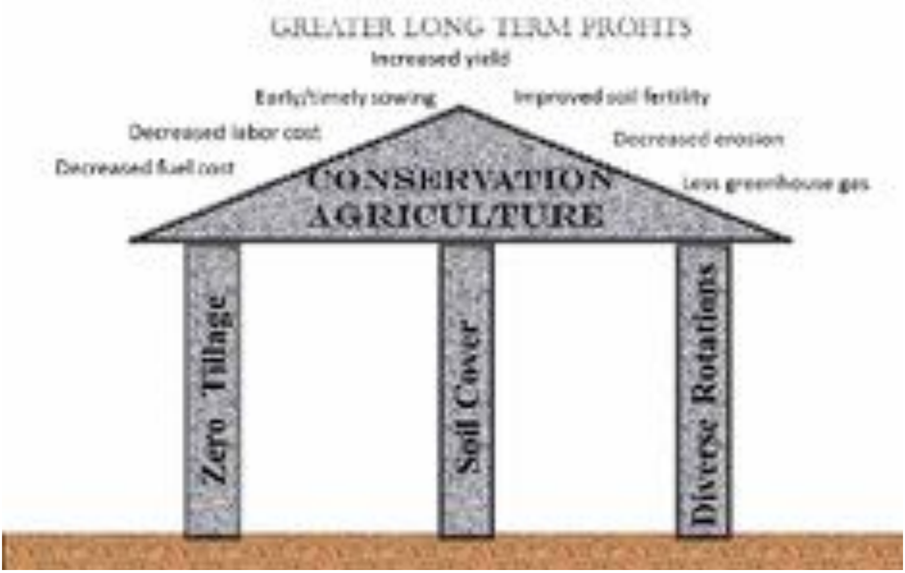

Figure 16. A mainstream model of CA with the three key principles acting as equal 'pillars' which produce a range of benefits, leading to greater long-term profits.

Some academics have even advocated strict definitions on the three pillars, decreeing that good CA should have no more than 20% soil disturbance, at least 30% ground cover at all times, and at least three different crops in the rotation. In our opinion, this rigid view of CA is not helpful for achieving widespread adoption, even if it is agronomically justified. There should be considerable flexibility and recognition that different technologies may be more or less important in different regions, cropping systems and individual circumstances.

As a result of the Iraq project, researchers and farmers have modified the model of CA for the Middle East by placing a strong emphasis on ZT and early sowing of crops, which becomes the main central pillar. They have shown that significant cost savings and yield increases can be produced without changes in soil cover and/or rotation, and a type of CA is possible with only ZT and early sowing (Fig. 17). In our experience, crop rotation is probably more important than soil cover, and this is indicated by the thickness of the pillars in Fig. 17. In some dry parts of Australia, many farmers are taking a pragmatic approach and using a similar model of CA.

We are not arguing that farmers in the Middle East may not benefit from diversifying their rotations, and in some cases, retaining crop residues to improve soil fertility. The three pillars remain important in maximizing the benefits and producing a stable cropping system. But in practice the decision to adopt different crops or retain crop residues is not as straight-forward as a change to ZT, because new crops and residue retention may reduce farm incomes, at least in the short-term.

In our experience, farmers who adopt ZT and early sowing usually saw immediate benefits, and after two or three years many started to become more interested in the other principles of CA. The successful adoption of CA is a gradual process, and innovative farmers around the world (including Australia) are constantly modifying their cropping practices to make their farms more sustainable and productive. This gradual approach is a key risk management strategy which delivers lasting adoption.

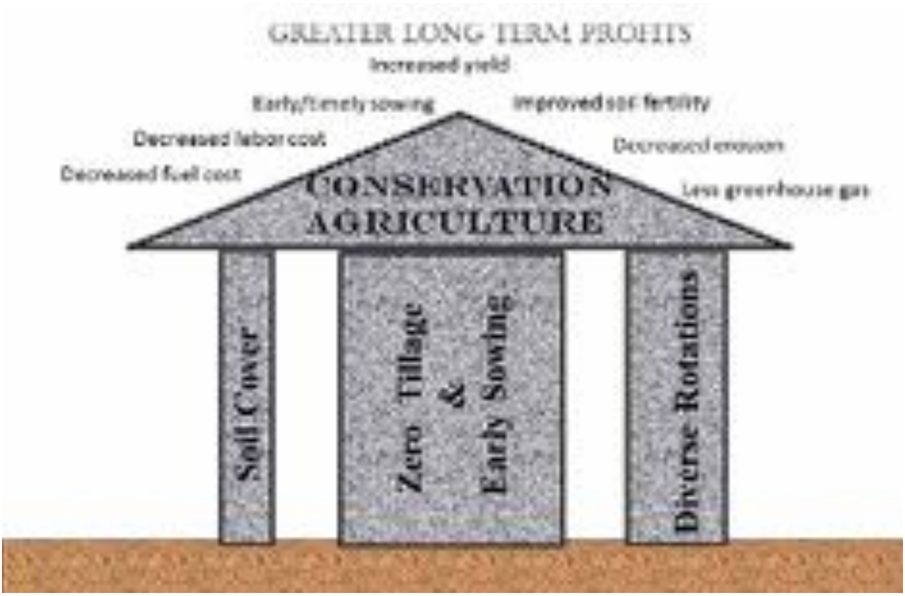

Figure 17. A Middle Eastern model of CA with zero-tillage and early sowing forming the main central 'pillar' which is capable of producing many benefits, even without soil cover and rotation. The three pillars remain important in maximizing the benefits and producing a stable cropping system.

3.0 Zero-tillage seeders

3.1 Definitions of tillage systems

In the Middle East and many other parts of the world, ZT is the key to the development of CA systems, and the ZT seeder is a critical piece of machinery. As CA is adopted so widely around the world, there are some differences in terminology used between regions, and some confusion among farmers, farm advisers and researchers regarding the definitions of tillage systems, machinery, and seeding operations. To avoid this confusion, it is important to accurately describe the type of tillage, equipment, and the sowing system.

In this publication we use the following definitions, in decreasing order of soil disturbance or movement:

Conventional tillage (CT) – traditional multiple tillage operations either with a mold-board, disc, duck-foot or chisel plow or harrows, followed by sowing with a conventional disc or duck-foot tine seeder causing another relatively high disturbance operation. This is also known as conventional cultivation or traditional tillage.

Minimum tillage (MT) - one tillage operation where 100 per cent of the soil surface is disturbed before sowing. In most cases the seeder also causes relatively high disturbance.

Direct drilling (DD) – tillage operations are eliminated before sowing, and the sowing operation is conducted directly into undisturbed soil. The seeder typically disturbs most, if not all of the soil surface, usually with duck-foot openers, but a proportion of crop residue may remain on the surface after the seeding operation. These DD seeders (also known as culti-drills) have a mix of cultivating openers at the front solely for tillage, followed by sowing openers which place fertilizer and seed in the soil. A second set of cultivating openers might then follow at the rear of the seeder to cover the seed in the furrows.

Zero-tillage (ZT) or no tillage (NT): tillage operations are also eliminated before sowing, but the sowing operation typically disturbs only a minority of the soil surface, in continuous furrows. In Australia, NT is typically associated with tine seeders while ZT is associated with disc seeders. But these terms are often interchanged in many areas of the world, so the term ZT is used to describe this category in this publication. The final level of soil disturbance in ZT varies with the type of furrow opener, operating depth and row spacing. It can range from very low disturbance (e.g. narrow slots with little visual effect of the sowing pass, such as with single disc openers) to relatively high disturbance (e.g. band sowing with wide openers generating significant amount of soil disturbance and movement).

The techniques of MT, DD and ZT fall under a broader category of conservation or reduced tillage, meaning less tillage than the traditional methods. Many farmers and researchers struggle with the idea that crops can be grown without any tillage before sowing – these are more likely to accept MT as an alternative rather than ZT. While the number of tillage operations and amount of soil movement is reduced in MT compared to CT, 100 per cent of the soil surface is disturbed leaving the soil prone to erosion and soil evaporation. Research in Syria, Iraq and elsewhere has shown that MT provides some benefits compared to CT, but ZT is far superior to MT. We generally encourage farmers wanting to try CA to go straight to a ZT which provides greater savings and other benefits compared to MT.

Interestingly, DD is not new to the Middle East. In some areas, if the first seasonal rains are late and the farmers have not cultivated their fields, they sometimes sow their crops with a conventional seeder without any prior tillage operations where the soil is suitably soft. This technique is called "skin planting". Contrary to expectations, these crops establish, grow and yield reasonably well if the subsequent rainfall is favorable.

Recommendation: Farmers wanting to try CA should be encouraged to go straight to a ZT approach which will provide greater savings and other benefits than MT.

3.2 Key seeder components

The purpose of a seeder (sometimes called a planter or seed drill) is to sow seed into an optimum environment that promotes rapid germination, complete and uniform emergence, and good early crop vigor. Any problem that occurs at sowing will impact crop establishment, growth and yield, and the best management of the crop for the rest of the growing period may be unable to correct the seeding error. Therefore, it is critical that the seeder is designed to work effectively under a range of conditions, is set up and calibrated accurately, is operated carefully and correctly, and is well maintained before, during and after use.

All seeders have three basic functions, which are to:

1. open the soil, usually in a furrow or slot,
2. place the seed and fertilizer into the soil at the desired depth,
3. close the furrow, ensuring sufficient soil cover and good contact between the seed and soil.

Whether small or large, seeders usually have four main components:

1. A frame (or chassis) comprising of tool-bars, a tractor hitch system, and adjustable depth gauging wheels.
2. A box (or hopper or bin) for seed and a box for fertilizer - these boxes are sometimes combined for simplicity.
3. A ground drive and metering system for each box and tubes to deliver the desired quantity of seed and fertilizer to the row seeding system. The metering system is normally driven from the seeder wheel (or another ground drive mechanism) and can be calibrated to vary the rate of seed and fertilizer independently of the ground speed. The rate adjustment is made via a speed gear box or a metering unit displacement controlled by a lever. For most seeders less than 4m wide, the flow of seed and fertilizer from the box to the seeding system relies on gravity, unlike many large seeders which use fans to assist the flow.
4. The row seeding systems, each comprising of the following elements:
   a) *soil openers*, either rotating disc blades or a knife/inverted T opener, mounted on a spring loaded arm or tine assembly which cut a continuous furrow or slot into the soil. These define the two main categories of disc or tine (also known as hoe or shank) seeders.
   b*) seed and fertiliser banding boots*, which are attached to the arm/tine assembly and deliver the seed/fertiliser into the furrow.
   c) *furrow closing devices*, either harrows, snake chains, or press-wheels, which cover the seed and improve the contact between the soil and the seed.

3.3 Zero-tillage and conventional seeders

The challenge for a ZT seeder is to operate effectively in undisturbed soils which are usually more dense and tougher than recently cultivated soils while minimizing soil disturbance. In CA systems, ZT seeders also need to be able to operate in the presence of crop residues or stubble, either standing stems attached to the roots, and/or pieces of straw and plant material lying on the soil surface.

The ZT seeder must minimize the disturbance of the residues and manage the tendency for them to accumulate into clumps around the seeding system, which may cause blockages and poor emergence. Poor crop emergence typically occurs when seeds are placed in contact with residues (e.g. hairpinning with a disc opener) or furrows are covered by large clumps of straw. As we will discuss later the ZT seeder may also need to separate the placement of seed and fertilizer in the furrow to avoid toxicity problems.

To meet these extra challenges, ZT seeders differ from conventional seeders in terms of the opener design, the break-out force (BOF) required to operate in undisturbed ground, row spacing and seeding system layout, box and frame height, and closing device. Other design features may also differ (e.g. overall robustness of the frame must be increased) but these aspects are not covered in this publication.

The ZT seeder is a critical part of the CA system, and farmers and researchers should carefully evaluate its main features and capacities before purchasing any seeder to make sure it will meet its purpose. While some manufacturers can be a valuable source of information about their seeders' capacities and suitability to a range of conditions, much useful information can also be gained from leading farmers and researchers who have had practical experience with ZT seeders.

3.31 Openers

There are essentially two types of openers used in ZT, namely the rolling disc blade, and the knife or inverted T opener, also called 'narrow points'. The openers are mounted on a spring-loaded tine assembly (Fig. 18).

Disc openers are able to cut through thick residues under the right conditions, creating a narrow slot in the soil with little visible disturbance or soil/residue mixing. By following the contours of the soil surface, they also have the capacity to place fertilizer and seed accurately into the soil. From this point of view, disc seeders are very attractive for CA systems. However, disc seeders have a number of disadvantages compared to tine-type seeders.

Zero-tillage disc seeders must be heavier than tine seeders to enable them to penetrate the untilled soil and cut surface residues. In comparison, tine-type ZT seeders with narrow points that are angled forward are better able to penetrate hard soils, break-up hard pans and require less or no downward force to operate, making them lighter and particularly suitable for farmers with small tractors. Tine seeders are less complex, with fewer moving parts requiring maintenance. Disc seeders are typically more expensive than tine-types because of their extra complexity and weight.

Importantly, tine seeders cope well with difficult stony or sticky clay soils, and are better able to produce adequate furrow tilth in soils with degraded structures, especially during the transition from CT to ZT. In Australia and Canada, most ZT farmers have typically adopted tine seeders for all of the reasons listed above. But recently, some experienced ZT farmers in Australia are now opting for low soil disturbance and high residue capacity disc seeders.

Figure 18. Examples of Australian seeding systems - a simple spring loaded tine (left), and a heavy duty single disc with gauge wheel (right).

Tine ZT seeders are not without their own problems. In general, they usually create more soil disturbance than discs, and are prone to accumulating stubble in thick and long crop residues, although these issues depend upon the design of the seeder. Instead of cutting residues like a disc blade, a tine deflects the residue away from the furrow.

Thick crop residues are uncommon in rainfed systems in the Middle East where crop yields are relatively low and grazing is widespread, so seeders designed to manage large amounts of residues are rarely necessary. Provided the row spacing and other seeder characteristics are appropriate (see section 3.33), the ability of tine seeders to handle residues is more than adequate for rainfed systems, especially in low rainfall areas. In irrigated crops, when high grain and biomass yields are expected, extra attention to residue management is required with both tine and disc seeders.

Recommendation: Tine-type seeders are generally lighter, simpler, cheaper and better suited to a wide range of soil types than disc-type seeders. If designed and operated correctly, tine seeders can play a major role in simplified CA systems for the Middle East.

The design of the tine-opener is critical in minimizing soil disturbance, placing fertilizer and seed in the soil, and creating a favorable environment for rapid seed germination, seedling emergence and early crop growth. There are numerous designs and types of tine-openers, each with advantages and disadvantages in certain circumstances (Fig. 19), but we will not go into these details here.

The easiest way to reduce soil disturbance in the Middle East is to use narrow knife points rather than the traditional duck-foot or other conventional openers. Narrow openers have the added benefit of reducing the draft force required, which is important in tough undisturbed soils.

Figure 19. A selection of tine openers or narrow points with specific design features causing varying levels of soil disturbance.

When sowing into undisturbed, compacted and abrasive soils, standard steel openers can wear quickly and develop an inefficient shape at their cutting edge which reduces their efficiency dramatically. Badly worn openers (Fig. 20) also do not penetrate the soil as effectively as new openers, and can create soil compaction and smearing at the bottom of the furrow making root penetration difficult. In some high wearing situations, conventional duck-foot openers may only last 2-3 hours under ZT before they need to be replaced.

While the type of steel alloy used and heat treatment applied to the opener will influence its overall durability, it will not affect the poor shape as it wears. The incorporation of extremely hard materials such as tungsten carbide into the opener design can increase its durability and enable it to wear evenly maintaining an efficient shape. Tungsten carbide material is exceptionally tough and expensive, so it is only used on the leading edge of the opener and other susceptible places exposed to high abrasive stresses (Fig. 21).

While protected openers cost more, their increased life span and improved performance make them cost effective in the long run compared to unprotected openers. In Australia and North America where large areas are planted each year with ZT tine seeders, protected points are used almost exclusively, but at present they are not commercially available in the Middle East.

Figure 20. Badly worn knife openers (left) with a characteristic "bullnose" rounding at the leading edge will not penetrate the soil as effectively as a new opener (right).

Figure 21. These Australian openers have tungsten carbide protection to enhance their durability and efficiency. The two on left have rough areas on the tip and wings where small tungsten carbide chips were welded on to the opener which is less expensive than the tile option (right) but is less durable.

3.32 Break-out force

Most seeders have a mechanism that allows the opener to operate at the correct depth in normal soil conditions, but when it encounters an obstacle in the soil, the opener is capable of lifting and riding over the obstacle without damaging the seeder. This safety feature is called 'breaking out', and is typically controlled by a spring mechanism as illustrated in Fig. 22 for a tine seeding system. In more advanced seeders the break-out mechanism may be controlled by a hydraulic system instead of a spring.

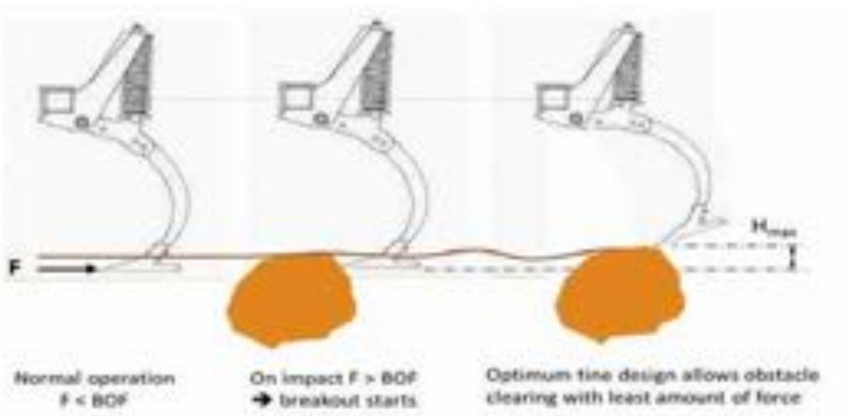

Figure 22. An illustration of how a well-designed spring release seeding tine is capable of clearing a large stone in the soil, when the break-out force (BOF) is exceeded upon impact with the stone.

The spring applies a downward force and keeps the seeding tine in place against the natural resistance of the soil (F). The force of the obstacle applied on the opener which initiates the tine break out movement is called the 'break-out force' (BOF) of the tine. The force of the soil against the tine is much greater in undisturbed soils compared to recently cultivated soils, and if it exceeds the BOF, then the tine is pushed back and upwards reducing the seeding depth. Hence, ZT seeders require greater BOF compared to conventional seeders in most soils.

A sufficient BOF is important to ensure the openers operate correctly in normal sowing situations, but allow them to clear any obstacles which may otherwise damage the openers. The clearance height or 'jump height' (H_{max}) during the breaking-out movement is also an important feature of ZT seeding systems when operating in difficult and stony soil conditions.

The BOF of the tine may be increased with an adjustment on the spring, however in some cases this may be insufficient, and a stronger spring or double springs may be required. Compared to conventional seeders, the tines on ZT seeders also have to be suitably strong to manage the greater soil forces, especially in stony soils, otherwise they may become damaged.

3.33 Row spacing and tine layout

In addition to using narrow knife openers, a complementary way to reduce soil disturbance and draft requirements is to increase the space between furrows, known as the row spacing. This has the added benefits of increasing the capacity of the ZT seeder to sow into crop residues, and reducing the weight and cost of the seeder. Row spacings in the Middle East are traditionally 15-18 cm for cereal crops, but research experiments and farmer experience in low rainfall areas show that this can be increased to 20-25 cm with no yield penalty. In dry conditions, cereal yields may even be increased with rows up to 30 cm apart, especially if crop residues help prevent soil evaporation and weed growth between the rows.

In addition to increasing the row spacing, the tines can be spread further apart by increasing the distance between the ranks (or rows) of tines, and/or increasing the number of ranks of the seeder. It can be seen in Fig. 23 that the spacing between the tines is considerably larger in the ZT than the conventional seeder, as a result of the combination of increased spacing between ranks, the addition of an extra rank, plus the wider row spacing. In this example, the row spacing was also increased from 18 to 27 cm, reducing the number of tines from ten to seven, and thereby greatly improving the ability of the seeder to handle heavy crop residues.

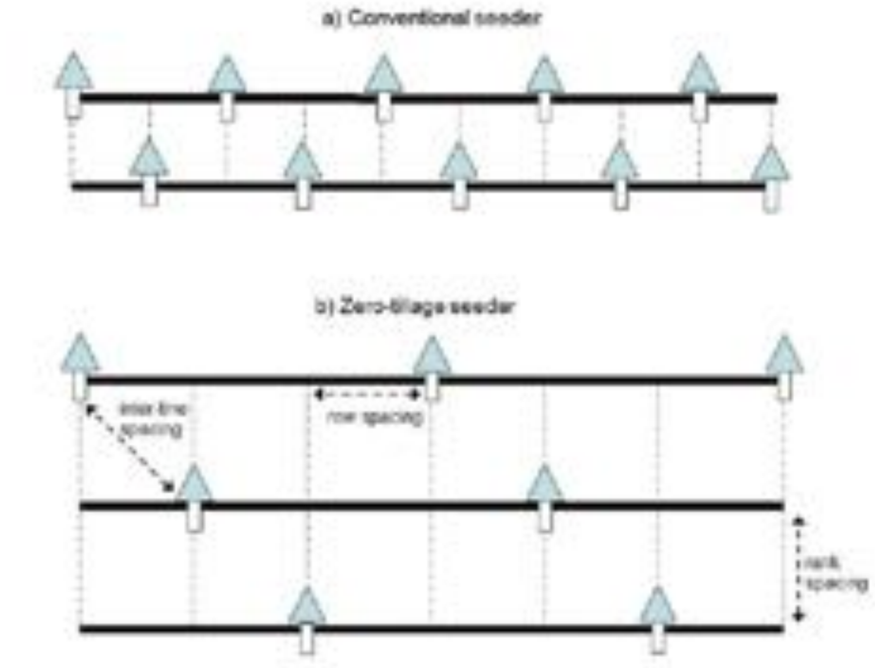

Figure 23. An illustration of tine layouts viewed from above for a) a conventional seeder with narrow row spacing on two narrow ranks, and b) a ZT seeder with wider row spacing on three wider spaced ranks for improved residue handling.

3.34 Box height, frame height and tine length

A problem with increasing the rank spacing and/or number of ranks is that angle of the tubes connecting the seed and fertilizer boxes to the seeding systems will suffer from reduced slopes, making them more prone to intermittent flow of seeds or fertilizer, and possible blockage. This is illustrated in the basic ZT seeder b) in Fig. 24 which has wider spaces between the ranks and an extra rank of tines compared to the conventional seeder a). However, sections of the tubes going to the front and rear tines of the basic ZT seeder are close to horizontal making the flow of seeds and fertilizer irregular.

The only way to overcome this problem, without employing a complex fan-forced system, is to lift the box to restore a sufficiently steep angle of the tubes and facilitate easy flow of the seeds and fertilizer to the openers. This can be seen in the improved ZT seeder c) in Fig. 24. This seeder also has the extra feature of longer tines and a greater clearance under the frame which improves both the angle of the hoses and the flow of crop residues through the tine layout.

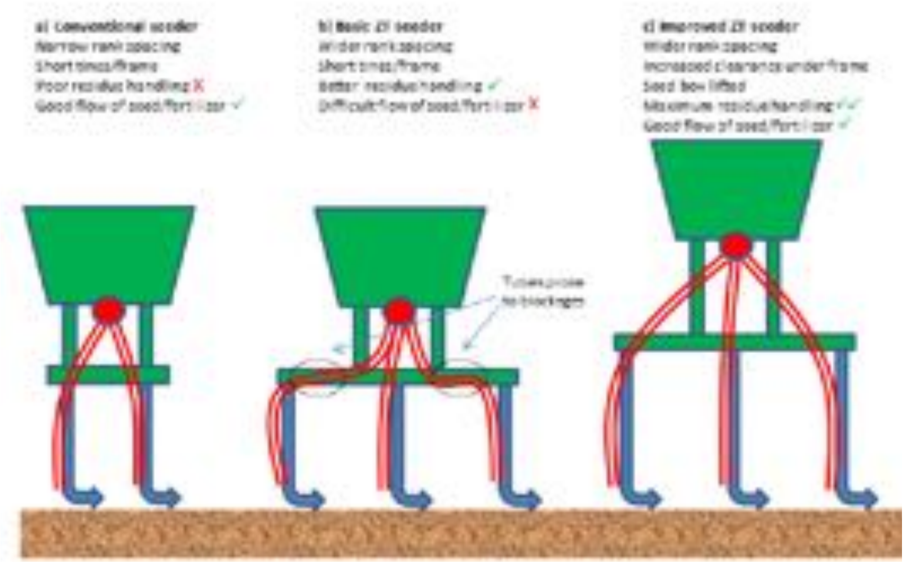

Figure 24. An illustration of three seeder configurations viewed from the side with different rank spacing, tine length, box and frame height. Note the flat angle of the tubes in configuration b) promotes irregular seed and fertilizer flow and can create areas prone to blockages. The improved ZT seeder configuration c) is recommended as the ideal model.

In situations where seeder height must be restricted (such as in orchards), a compromise solution may consist in a two rank ZT seeder configuration as in seeder a), or a ZT seeder like c) but equipped with a narrow hopper (e.g. 50-60% of frame width) where the outside outlets may still connect to the outside tines of the frame with sufficient angle.

3.35 Seed and fertilizer placement

In ZT systems, it is critical that the phosphorus (P) fertilizer is placed close to the seed. Unlike nitrogen fertilizer which is highly soluble and can be washed by rainfall into the soil and zone of root growth, P is much less soluble and is not highly mobile in soils. If P fertilizer is spread on the soil surface and is not incorporated, it will only move 2-3 mm into the soil below each granule which is often dry making the P mostly unavailable to the plant roots. Even if the P fertilizer is spread on the soil surface and then incorporated by tillage, it is less available than fertilizer placed near the seed because the roots have to explore more soil to come in contact with the granules.

In many cases seed and fertilizer can be safely placed in the soil together with ZT seeders, especially if the rate of fertilizer is low and the row spacing is narrow. But high rates of fertilizer, such as those applied under irrigated conditions, can be toxic to the germinating seeds when they are placed in close contact.

The amount of fertilizer toxicity damage depends upon many factors:

1) the type and rate of fertilizer applied,
2) the row spacing and opener, especially the opener width, which influence the lateral and vertical spread of seed and fertilizer (wide row spacings and narrow openers have high risk),
3) the crop (large-seeded crops like faba bean tend to be more tolerant than cereals),
4) soil type (fine-textured clays are safer than sandy soils), and
5) soil moisture conditions (toxicity is more likely under marginal soil moisture).

Row spacing is especially important for managing fertilizer toxicity – when the row spacing is doubled and the fertilizer rate per hectare remains unchanged, twice the amount of fertilizer is concentrated in each row, and the risk of fertilizer toxicity is vastly increased.

Urea and ammonium sulphate are especially toxic and should never be applied with or close to the seed. Other fertilizers (e.g. diammonium phosphate, DAP or triple super phosphate, TSP) are less toxic. The easiest way to avoid toxicity damage is to separate the fertilizer from the seed by 3-4 cm in the soil. Fertilizer is normally placed below the seed as illustrated in Fig. 25, or in more sophisticated seeding systems, below and to the side of the seed. Some seeding systems provide better separation than others, and the separation distance should be checked carefully if fertilizer toxicity is possible.

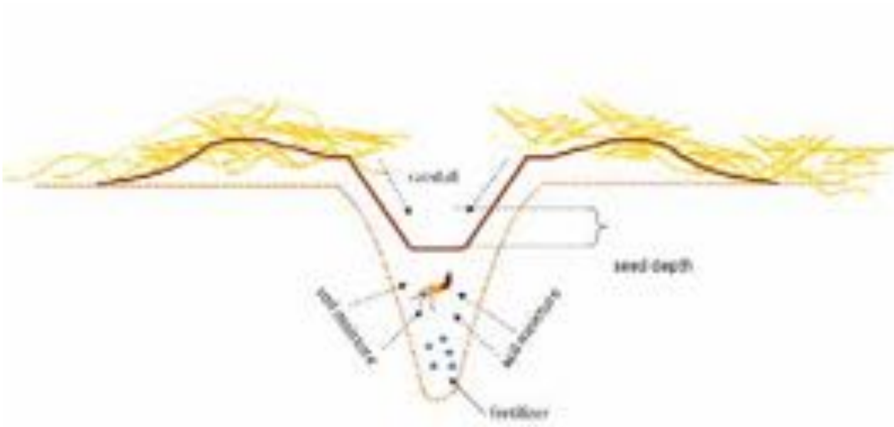

Figure 25. A cross section of the furrow after tine seeding showing the soil moved by the opener ('soil throw') and crop residues on the inter-rows, the effect of the press wheel on furrow shape promoting water harvesting, and separate seed and fertilizer placement produced by a split seed and fertilizer banding system.

Recommendation: In general for cereals when using 23 cm row spacing and narrow points, seed and DAP fertilizer does not need to be separated if the rate of DAP is less than 100 kg/ha.

3.36 Closing devices

The closing device of the seeder ensures that the furrow closes adequately, and the seed is covered with sufficient soil. Spring or chain harrows used in conventional seeders are designed to leave a flat soil surface and have difficulty in CA systems because they tend to accumulate the crop residues in large clumps, may generate blockages, and create unwanted soil disturbance (Fig. 26).

Figure 26. This Turkish made conventional tine seeder sowing into an uncultivated soil with low residue in Palestine is equipped with covering spring fingers. Note the accumulation of crop residues around the tines (bottom right) and spring fingers after a short distance, which is likely to cause seeder blockage. A disc marker arm is being used (bottom left) to help the driver align each run of the seeder and eliminate gaps or overlaps.

Simple ‘snake chains’, as shown in Fig. 27, provide enough soil disturbance and only in the furrow to help back-fill the furrow and cover the seed. These are cheap, light and do not accumulate residues. Snake chains should not be attached too high on the boot or tine to ensure they do not bounce in operation. In stony soils however, these can act like small hammers and damage the seed boots as the tines break-out and recoil back rapidly.

Figure 27. A 'snake chain' tine attachment with end disc can be a simple furrow closing device on a ZT seeder, particularly suited to light soil conditions.

In many parts of the developed world, the use of furrow press wheels is common. Press wheels are used to help develop an optimum furrow environment and ensure rapid crop germination and emergence in both CT and ZT systems. In their common form, they apply a downward pressure on top of the furrow which firms the soil around the seed to provide good contact between the soil and seed, and promote rapid water transfer from the surrounding soil to hasten seed germination (Fig. 25).

Press wheels come in numerous shapes, sizes and materials. Wide press wheels with angled sides leave a furrow shape which can capture rain from small rainfall events and direct the water into the bottom of the furrow towards the seed zone, in a water 'harvesting' effect (Figs. 25 and 28).

The disadvantages of furrow press wheels include their extra weight, complexity, maintenance and cost. If they are not well designed they can also accumulate wet sticky soil which stops them operating correctly, and excessive downward pressure can also create compaction above the seed, which may significantly reduce crop emergence. The design of the press wheel (including adjustability), the selection of an appropriate type to match the opener, and the operation in the field are critical in maximizing their benefits and managing any risks.

Figure 28. This Australian press wheel has a wide angle creating a large and stable furrow surface shape (right) which can 'harvest' water during small rainfall events and concentrate it near the seed (left).

3.4 Converting CT seeders to ZT

In many parts of the world where suitable ZT seeders were not initially available, including Australia and the Americas during the 1970s, innovative farmers modified their existing conventional seeders to allow them to sow directly into undisturbed soil. In the Middle East a number of seeder have been effectively converted to ZT with minimal cost - John Shearer from Australia, Rama from Jordan, Nardi from Italy, and local Syrian seeders. Conversion was especially popular in Iraq where local manufacturing of ZT seeders was slow to start.

The main changes required to convert conventional seeders for ZT are as follows:

1) remove any cultivating tines and harrows if present,
2) replace the conventional openers (e.g. wide duck-foot) with narrow low disturbance openers,
3) increase the BOF of the tines by tightening the spring mechanism. If the BOF is still inadequate after adjustment, a higher resistance spring may be required, or a second spring of appropriate specifica-

tions can be added inside the first. The spring release mechanism must enable the full jump height without the springs undergoing permanent deformation.

4) lift the seed and fertilizer boxes if the angle of the hoses is a problem (as shown in Fig. 24). Typically the boxes should be raised 30-40cm or more. If using C shape spacers, they must be strong enough to resist buckling under weight and combined with side braces to provide good lateral rigidity. Ideally, the centre of the hopper outlets should be located over the centre of the ranks, to equalize the angles of the front and rear hose. Lifting the boxes will also require a modification to the ground drive mechanism, which usually consists of a longer drive chain, and extending or modifying the chain guard as needed.
5) consider increasing the inter-tine spacing if the crop residue levels might be large. This can be obtained by widening the row spacing and re-distributing the seeding tines accordingly. The front and rear ranks used previously for cultivation or furrow closing tines, can also be used for seeding tines provided the angle of the hoses is not compromised. If the new tine layout results in fewer seeding tines being used, the number of unused outlets from the box will need to be closed off.
6) consider a seed covering device such as snake chains or press wheels. The design of the press wheel assembly can be tailored to attach to a separate tool bar or to share the rear tool bar with seeding tines if needed.

Figure 29. Mr. Ghazi Fathi from Mosul Iraq convertedhis Rama seeder to ZT and installed locally made press wheels.

In the example shown in Fig. 30, the inter-tine spacing of a 3.6m Rama seeder was increased by changing the row spacing from 17 cm to 22.5 cm, and spreading the sowing tines over three ranks instead of two. It was determined that the insufficient angle of the hoses for the extra third rank was likely to cause blockage problems, so the seed and fertilizer boxes were raised by 43 cm by making and inserting two spacers or brackets. Snake chains were also fitted later.

Figure 30: This conventional Rama seeder at Ainkawa Research Centre, Iraq, was converted to ZT by modifying the row spacing and tine layout, and installing narrow openers. Note the inserted black spacers to lift the seed and fertilizer boxes to create sufficient angle for the hoses. The new tine layout had a good capacity to handle crop residues (right).

3.5 Local manufacture of ZT seeders

Most ZT seeders made in North and South America and Europe are inappropriate for small to medium farmers in the Middle East (Fig. 31). They are usually large disc-type seeders, which are relatively expensive and heavy, have many complex moving parts requiring maintenance, and are less able to cope with hard, stony or sticky clay soils compared to tine seeders. Many countries in the Middle East have small local workshops that manufacture and repair simple conventional seeders and other agricultural machinery and if given the right technical support, these are capable of producing simple and affordable ZT seeders.

Figure 31. These Brazilian and Italian disc ZT seeders imported into the Middle East can perform well in suitably mechanized ZT systems, but are relatively complex, heavy and expensive for small farmers.

As part of the project led by ICARDA and funded by ACIAR, Australian agronomists and agricultural engineers and project staff worked with local workshops in the region to develop their knowledge and expertise in ZT seeder technologies, design, function and fabrication. These workshops were able to produce simple but effective ZT tine seeders, both trailed and tractor-mounted, at prices affordable for most small to medium farmers. This also meant parts and repairs could be sourced by farmers relatively quickly, and created much needed local employment.

Manufacturing was particularly successful in Syria where eight village workshops were producing ZT seeders at low prices before the outbreak of civil unrest in 2012 (Fig. 32). In many cases the Syrian manufacturers became advocates for the promotion of the ZT technology, and were actively involved in local ZT farmer groups. This benefited their businesses by increasing the number of seeders sold, but also enabled them to receive excellent feedback on the performance of the seeders and develop improvements in ZT seeder design of their own initiatives. This is discussed further in section 7.1.

Figure 32. Some examples of simple, effective and low-cost ZT tine seeders manufactured in Syria. These dual hopper seeders are 2.3 to 3.8 m wide with a 2012 price range of US$2,500 - 6,000.

In northern Iraq, two workshops in Mosul produced ZT seeders in close collaboration with a group of leading farmers, while in Iran several manufacturers with limited interaction with the project produced effective tine ZT seeders (Fig. 33). In Jordan, Rama Agricultural Equipment Manufacturing also made ZT seeders in 3.6 m (trailed) and 2.3m (3 point linkage) widths (Fig. 34).

Figure 33. Field testing of the Ras Alrumh ZT seeder made in Mosul (right), and Mr. Sarmad Khalid, Directorate of Agriculture Kirkuk Iraq, discusses the ability of this Iranian ZT seeder to operate in heavy crop residues (left).

Figure 34. An example of the Rama 3 point linkage tine ZT seeder (dual hopper and 10 tines, 2.3m wide) made in Jordan in 2014 with an approximate price of US$7,000

3.6 Seeder calibration

Like any piece of agricultural machinery, unless the seeder is accurately calibrated, and set up and operated correctly, it will not produce the desired depth and uniform spread of seed placement in the soil, rapid seed germination, consistent emergence at the desired density, and good early crop vigor. As mentioned previously, any problem that occurs at sowing will impact crop establishment, growth and yield, and very little can be done to correct the problem later in the growing season.

The metering system should be calibrated to deliver the desired rate of seed and fertilizer with good accuracy. While the calibration tables developed by the seeder manufacturers may be reasonably useful, the rates delivered may vary significantly depending upon the batch of seeds or fertilizer, the humidity in storage, seed treatments, speed of operation, field conditions and other factors such as the amount of vibration during operation and potentially, the amount of seed or fertilizer in the box.

Recommendation: Well before the start of each sowing period check the operation and seed/fertilizer calibration for your seeder using the seed and fertilizer batches intended for that season. This will also give you time to organize repairs if needed.

Make sure that the seed and fertilizer are free from sticks, stones, lumps and other debris that may cause blockages. The awns on barley seed make it especially prone to blockages, and in some cases removing the awns by screen cleaning may be required. If fertilizer was not been stored correctly it may have developed clumps, which should be broken up through a mesh that is sufficiently fine. Cleaning the seed and fertilizer should be done before calibration.

The desired sowing rate of seed can be calculated from the plant density required to optimize crop yield (**target plant density**), the viability of the batch of seed (**germination test**), and the likely losses in the field after sowing due to insects and other pests, difficulty with emergence, etc. (**field losses**) in the following formula:

plants/m² (targeted density) *grams / 1000 seeds* (seed weight)

$$\text{Seedrate (kg/ha)} = \frac{\text{targeted density} \times \text{seed weight}}{100 \times [(1 - \text{field losses}) \times \text{seed germination}]}$$

per cent (field losses) *per cent* (seed germination)

For example, if you are targeting 150 plants/m^2 and have a batch of seed with an 89 per cent germination rate, a mean seed weight of 40 g per 1000 seeds, and expect 10% field losses, then the following formula applies:

$$\text{Seed rate} = \frac{\mathbf{150} \times \mathbf{40}}{100\times[\ (1-\frac{\mathbf{10}}{100}) \times \frac{\mathbf{89}}{100}]} = \mathbf{74.9}\ \text{kg/ha}$$

The agronomic optimum plant density for each crop may vary depending upon the variety used, and will be affected by local conditions such as season rainfall and soil type, weeds, and whether the crop is primarily harvested for its biomass (hay) or grain yield. These optimums should be determined by field experiments and farmer experience over many seasons (see section 2.44).

To calibrate the seed or fertilizer metering system, we recommend measuring the output from all hopper outlets while the seeder operates for the equivalent of 1 per cent of a hectare, or 100m^2 (Fig. 35). ☐

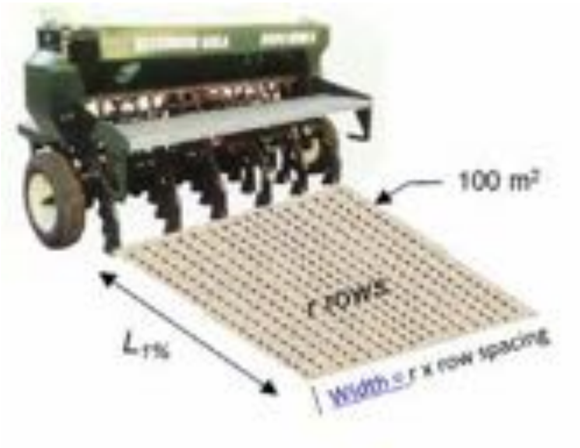

Figure 35. The calibration of seed and fertilizer rates can be estimated from the distance travelled ($L_{1\%}$) required to sow 100 m^2 for this seeder equipped with *r* tines set at a given row spacing.

The distance the seeder needs to travel to seed 100m^2 ($L_{1\%}$) will depend upon the sowing width, which is the number of tines or rows (r) multiplied by the row spacing, as below. For example, if the seeder has 10 tines set on 0.22cm row spacing then the distance $L_{1\%}$ is 45.5 m.

$$L_{1\%}\,(m) = \frac{100}{r \times \text{row spacing}}$$

Number of seed rows (r); *meters* (row spacing)

$$L_{1\%}\,(m) = \frac{100}{\mathbf{10} \times \mathbf{0.22}} = \mathbf{45.5}\,m$$

As the seeder is ground driven, the number of turns of the driving wheel required to travel the distance $L_{(1\%)}$ will depend upon the effective circumference of the drive wheel which can be estimated using measuring tape wrapped around the outside of the tire. The number of turns of the wheel required to sow 100 m^2 will be equivalent to the required distance ($L_{1\%}$) divided by the circumference in meters. For example, if the tire circumference is 1.89 meters, then this will require 24 turns to travel the 45.5 meters, and sow 100m^2 i.e. 45.5 divided by 1.89.

The effective circumference of the wheel may change slightly between soft, sticky and/or stony soils. For a more accurate measurement, the distance travelled in the field over 20 wheel turns can be marked and measured during a test seeding operation. The use of scrapers to prevent the build-up of mud on tires, limits changes in the tire circumference in sticky conditions.

To measure the output, we recommend lifting the seeder off the ground, securing it safely, and placing a large sheet of plastic to collect the seed or fertilizer from all outlets as shown in Fig. 36. Make sure the metering system is primed by turning the wheel 4-5 times before starting to collect the seed or fertilizer, and watch for any product bouncing off the plastic sheet. Using the manufacturer's calibration chart to determine the initial gear box or rate adjustment settings, select a starting point close to the desired rate. In our example above, we need to rotate the drive wheel exactly 24 turns for 100m^2.

Figure 36. The output of the seeder can be collected from all tines using a large sheet of plastic to estimate the average seed or fertilizer rate (left). The uniformity of output across the seeding tines can also be measured by collecting and comparing individual outlets using small dishes labelled for each outlet (right).

The weight of the seed/fertilizer collected from all tines should then be measured using an accurate set of scales, and the final output rate simply multiplied by 100. In our example, an output of 0.750 kg from 24 wheel turns is equivalent to 75 kg/ha. If the output is significantly different from the desired rate, then the gearbox or lever setting needs to be changed, either up or down as needed, and the output measured again.

Once the desired rate is delivered consistently (repeat the final check), then it is often useful to measure the output for each outlet separately to check the uniformity of delivery across the seeder. This can easily be done using a bucket, dish or plastic bag for each outlet (Fig. 36). While each outlet should not differ from the average output by more than 5%, it is common to find outlets deviating by 8-10%. Some adjustments may be possible to correct any outlets that vary by more than 5-10%.

Of course, the seed and fertilizer metering systems need to be calibrated separately, and once the seed calibration is completed, the same process must be repeated for the fertilizer system. At all times during the calibration procedure, ensure there is enough seed and fertilizer in the respective hoppers.

3.7 Field operation

Following calibration, the seed and fertilizer boxes can be filled and the seeder taken to the field. The level of seeder should be adjusted from side to side using the tractor lifting rod adjustment, and from front to back, to ensure the tines operate at a similar depth. A visual assessment after seeding a test strip is typically enough to detect any differences in level.

The seeder should be pre-set for the desired depth of seed and fertilizer placement to facilitate the field checks. The type of depth adjustment mechanisms varies from seeder to seeder and can be made by changing the opener operating depth, and/or by adjusting each individual seed or fertilizer banding boot, if possible.

In general, the ideal seeding depth for cereals is 4-6 cm (see section 2.43). As shown in Fig. 25, the agronomic or effective seeding depth is the distance between the seed and the soil surface above it at bottom of the furrow, i.e. the distance that the shoot has to grow to emerge. This is not the distance to the top of the ridges or the original soil surface, which may be quite different.

It is a good practice to check and if necessary adjust the seeding depth for each field, especially if the fields have different soil types or pre-sowing tillage operations. There is a tendency for operators to plant too deep in cultivated fields and too shallow in untilled soils. Check that the tine BOF force is sufficient in ZT fields – if it is set too low, then the tine will be pushed backwards and the seed depth will decrease perhaps with some seeds left completely uncovered. Ways to increase the BOF were mentioned in section 3.4.

Ideally, each run of the seeder along or around the field should be aligned with the previous run so that there is no gap or overlap between them. Large gaps are a waste of land, while overlaps result in double the seed and fertilizer inputs, resulting in reduced yields or excessive costs. The inefficiencies due to gaps or overlaps can represent a significant proportion of the field (up to 20%), particularly with small seeders in small fields. Drivers should be able to align the tractor accurately with the previous run, either by eye, or with the use of marker arms. The disc marker arm in Fig. 26 is one example. Low-cost guiding arms can also be adapted to any tractor, following the example shown in Fig. 37.

A common mistake by many seeder operators is to drive too quickly. Remember that with ZT you have eliminated plowing time and costs, so you can afford to take your time with sowing operations. Most seeders operate efficiently and achieve a uniform seeding result at 6-8 km/hr. Take special care in stony soils which may damage the seeding system if the speed is too high. Likewise, the speed should be reduced when sowing into hard dry soils, or if the soil is sticky, and/or heavy crop residues are present

Recommendation: While most seeders operate efficiently at 6-8 km/hr, the speed should be reduced if the soil is stony, dry and hard, or sticky, or if heavy crop residues are present. The quality of seed and fertilizer placement are always reduced at high speeds.

In addition to the increased risk of damage to the seeder, high speeds also cause excessive 'soil throw' i.e. the furrow created by the tines at the front of the seeder become filled by the rear tines which push excessive soil sideways. This will be evident as alternating seeding depth across the seeder runs – one or more furrows associated with the rear tines with good depth, furrow shape and plant establishment, next to others created by the front tines which had too much backfill resulting in poor shape, excessive depth, and patchy or delayed establishment (Fig. 38). The maximum recommended speed of operation does not create soil throw from one opener onto adjacent furrows and creates uniform furrows across the seeder.

Figure 37: An example of a cheap guiding arm developed by ICARDA at the Mushaghar experimental station in Jordan, eliminates overlaps or gaps between sowing runs.

Figure 38: Sowing at high speed creates excessive 'soil throw' and variable seed depth. Note how the rows created by the front tines have been covered by the rear tines and the only furrows visible were created by the rear tines.

Operating in fields with large amounts of residue can present challenges for many seeders. At present this is rarely the case in the Middle East, except perhaps under irrigated conditions. With any ZT seeder, working when the stubble and soil are dry considerably reduces the extent of straw clumping and risks of seeder blockage compared to wet conditions.

Operating at an angle to the direction of the trails of chaff and straw left behind the harvester can also avoid problems associated with the continuous operation of some tines within the trail. With row spacings more than about 23 cm, guide arms may be used to assist the driver to achieve inter-row sowing (see Fig. 7). This is a practice where the rows of the crop are sown between the rows of the previous crop to limit the restrictions caused by the crop residues and create a favorable seedling environment.

Making sharp turns at high speed while the seeder is in the ground puts high stresses on the tines or discs. Mounted seeders should only be turned at the end of each run after they have been lifted out of the ground. It is good practice to gradually lower the seeder to its operating depth while moving forward slowly to avoid blocking the seed and fertilizer delivery boots with soil. This is especially critical in wet and sticky soils. Also, avoid stopping with the seeder still in the ground. Never reverse while the seeder is in the ground.

Check the outlet of each hose for blockages regularly. Blockages can occur in the seed cup just under the box (e.g. with large or dirty seeds, or awned barley), in the hose (e.g. due to insufficient angle), or at the seed and fertilizer boot outlets (from wet sticky soil and crop residues). Regular checks for blockages, disconnected hoses and damage to the seeding systems are recommended every 20-30 minutes depending upon the sowing conditions. Low speeds can assist when sowing large seeds or seeds with awns, although the later are better de-awned prior to seeding to ensure trouble-free sowing.

Finally, make sure that the box does not run out of seed or fertilizer. Some boxes have a useful clear window (Fig. 39) or a float-type indicator to monitor the level of seed/fertilizer in the boxes. Sloping funnel-shaped inserts as seen in Fig. 39 can help ensure the outlets do not run out of seed or fertilizer when the box is almost empty, especially if operating in sloping fields.

Figure 39: A clear window (left) visible from the tractor seat is a low cost solution for monitoring the seed or fertilizer levels in the hopper. Funneling inserts at the bottom of the hopper are useful to ensure each outlet does not run out of product as the level gets low.

3.8 Seeder maintenance

Regular maintenance is critical to ensure good ZT seeder performance season after season. The objectives of maintenance of machinery are four fold:

1. to extend its useful life, reduce operating costs over time, and ensure maximum productivity and return on the investment,
2. to reduce the risks of breakdowns and need for repairs (ultimately reducing costs).
3. to ensure the immediate availability and readiness of the machine when needed,
4. to ensure safety of personnel who use the machine and bystanders.

Maintenance includes static inspections, checks during operation, routine servicing, repairing, modifying and overhauling activities.

So, every piece of agricultural machinery should be maintained regularly before, during and after operation. Seeder maintenance is a worthwhile investment in any cropping operation, especially if you have made an investment in a new ZT seeder. A month or so before commencing sowing, it is wise to do an overall check of the seeder and conduct calibrations with the batches of seed and fertilizer to be used. This will allow time if problems are discovered and repairs are required.

Replace or repair any parts showing excessive wear (e.g. openers), damage or fatigue (e.g. cracks or broken welds) and perished plastic/rubber hoses and other parts. Check and adjust the tension on chains as required. Ensure all nuts and screws are tight, and grease all appropriate locations. Check and adjust the operating range of all adjustments (depth, metering, etc.), tire air pressures, and oil levels (gear box) if relevant, and test for tight bearings or movements.

If the seeder is working for six hours per day or more, then a general check should be conducted each day usually before commencing seeding. All grease points should be filled including metal sprockets and chains. Plastic gear (e.g. chain tensioners) should not be greased. Check that the chains, springs and other moving parts are operating freely as designed, and inspect for loose bolts on moving parts, in particular on the seeding system. During operation, regularly check for damage to the seeding systems and blockages, especially when operating in stony or sticky soils, and beware of punctures to tire.

If the seeder has to be transported on roads from one field to the next, check that the seeding systems and closing devices are well clear of the ground, and drive cautiously at low speed to avoid collisions. At all times remember that the seeder is wider than the tractor. If the seeder is being loaded or unloaded to or from a truck using a ramp, make sure everyone's safety is paramount, and that there is little risk of dropping or damaging the seeder. If a fork-lift or crane are used, ensure that the lifting points are not going to damage the seeder – lift from the seeder frame, not the seed/fertilizer box.

At the end of each planting season, maintenance and proper storage is especially critical. The seed and fertilizer hoppers should be completely emptied and thoroughly cleaned including the metering system, seed and fertilizer hoses and banding boots. Fertilizer can be particularly corrosive to metal components, and it absorbs moisture from the air and can become very hard when it dries. Soil should be cleaned off all parts of the seeder. Driving chains should be cleaned with a degreasing agent, immersed in oil for several days, and then dried and refitted - take care to respect the direction of the 'quick link'.

Once the seeder is cleaned and dried, all grease points should be filled to push out any residual water. It is also wise to spray the seeder metal parts with a protectant coating (e.g. diesel and oil mix) to repel water and reduce the rate of corrosion, taking care to avoid some of the plastic or rubber components which may be damaged by the protectant - consult with the manufacturer. As much as possible, seeders should be stored out of the sun and rain, either under a plastic sheet or ideally in a shed. In particular, high temperatures and sunlight will hasten cracking and damage the rubber and plastic components. It is good practice to store the seeder on hard and dry ground and while taking the weight off the driving wheels.

Recommendation: ZT seeder should be checked and maintained regularly before, during and after operation.

4.0 Weed, Disease & Pest Management

Tillage is often employed to reduce the populations of biotic pests (weeds, diseases, insects, rodents, etc.) and the removal or incorporation of crop residues into the soil can also reduce their prevalence. So the switch to CA sometimes causes an increase in pest problems. However, in other cases ZT and the retention of crop residues can also suppress other pests.

Stinner and House (1990) reviewed the impact of ZT and CA on 51 insects and pests around the world. Overall, they found that while 28% of species increased with ZT practices, 29% showed no significant influence, and 43% decreased with decreasing tillage. This included increases in the populations of some ground-dwelling species which are natural enemies to pest species under ZT.

Research conducted in Syria and Australia and farmer experience shows that while the species of weeds, diseases and insects can be different between CT and CA systems, the overall size of the populations is generally similar, especially in low rainfall areas where the overall pest burden is often low. Nonetheless, special attention should be paid to the management of biotic stresses under CA, including the use of crop rotation. Sometimes this also means greater use of chemical sprays or the introduction of new types of sprays, and while this does not sit well with the principles of organic farming, compared to the damage caused by tillage, we believe the responsible use of pesticides is the "lesser or two evils."

While chemical control is one way of reducing the presence of weeds, diseases and insect pests, pesticides should be used as part of an integrated management program alongside techniques other than tillage, such as crop rotation, resistant varieties, ensuring high crop competition (e.g. early sowing), and general crop hygiene practices to prevent the spread of the problem, if these are available. The combination of control measures ensures a robust management system and reduces the risk of the development of resistance to pesticides or other control methods.

Like any other input, chemical sprays should be used efficiently and only when necessary. An over-reliance on pesticides can be costly, cause environmental pollution, and may lead to the development of resistance. Crop chemicals are normally applied by a boom-sprayer (Fig. 40) or perhaps with a backpack sprayer in small scale operations.

The use of pesticides in the Middle East is generally less common than other more advanced agricultural countries and application expertise and skills among Middle Eastern farmers are relatively low. Closer attention should be paid to monitoring the levels of weeds, diseases and pests before sowing and within crops, and employing control measures before crop yield is affected.

Figure 40. Most chemical sprays are applied with a boomsprayer which should be well maintained, calibrated and used in the appropriate way.

Just like the seeder, the spray application equipment should be well maintained, calibrated and used in the appropriate way so that they are effective, waste is minimized and the safety of the operator and nearby people are ensured. It is not our intention to go into the details of chemical application in this publication. Some chemical sprays are highly toxic to humans and the environment, so we recommend special precautions are employed with the handling and use of all chemical sprays.

Recommendation: Before using chemical sprays, read the product label carefully and follow the recommended handling, application and safety methods.

Recommendation: Always use gloves, goggles, overalls and respirator masks when handling and applying chemical sprays regardless of their toxicity.

4.1 Weed Management

Many fields in the Middle East have high weed populations, especially in medium and high rainfall areas, and the management of weeds is relatively poor by international standards. Weeds compete with the crop for moisture, nutrients and light, and can cause large reductions in yield. In both conventional and CA systems, farmers in the Middle East should pay greater attention to reducing the populations of weeds through a range of techniques.

In CA systems, weed seeds are not incorporated into the soil, but are left of the soil surface where they are exposed to insect predators and large fluctuations in temperature and moisture, which often reduce the seed viability. In addition, if large amounts of crop residues are retained on the soil surface, this will discourage the germination and growth of some weed species. On the other hand, large amounts of residues on the soil surface can reduce the effectiveness of herbicides which are applied to the soil and then taken up by the weed roots. But these herbicides are rare in the Middle East.

In most Mediterranean environments, the summers are hot and dry, and weeds are unable to grow because of lack of soil moisture. In some circumstances summer thunderstorms and early autumn rains will allow the establishment of weeds. If sowing is delayed, these weeds should be sprayed with a non-selective herbicide, like glyphosate (Roundup®), paraquat (Gramoxone®) or diquat (Reglone®), before sowing.

Glyphosate is taken up by the leaves of the plants and then translocated to the roots where it will kill the plant after 7-10 days. Paraquat and diquat rapidly kill green plant tissue on contact and small plants will dehydrate and die within 2-5 days. These non-selective chemicals are quickly deactivated in soils and will not damage germinating crops. So, the crop can be planted a day after spraying without any risk of damage.

Recommendation: If weeds are present before sowing, they should be sprayed with a non-selective herbicide, like glyphosate (Roundup®), paraquat (Gramoxone®) or diquat (Reglone®). The field can be sown safely the following day.

We advocate early sowing, as soon as possible before or after the first effective autumn rains, especially for wheat and barley (see section 2.42). Early sown crops emerge at a similar time as the weeds, and if the crop seedlings grow vigorously under warm conditions, they will compete well with the weeds for moisture, nutrients and light.

However, if the field has a large weed population, it may be wise to delay sowing until 10-14 days after the first rains to allow the weeds to germinate. Weeds can then be controlled with a non-selective herbicide (like glyphosate) immediately before sowing to dramatically reduce the weed pressure within the crop. The benefits of early sowing for legumes is less than cereals, so the delayed sowing strategy to allow weed management with non-selective herbicides might be especially suited to lentil. In the case of chickpea sowing can be delayed many weeks without much yield penalty.

Broadleaf and grass weeds can be managed in cereal and legume crops with the use of selective herbicides after crop emergence. Selective herbicides are relatively common in the Middle East, especially those controlling broad-leafed weeds in cereal crops. Their use is identical under CA and conventional crop management systems.

With most selective post-emergent herbicides it is particularly important to apply them at the optimum stage of development of the weeds to ensure a good kill. Similarly, crops are sensitive to damage from some herbicide at certain stages of development. Read the chemical label carefully and follow the recommendations closely. In general young small weed seedlings are easier to kill than older weeds.

Crop rotation is an important part of weed management, as it is for diseases and insects. There are many cheap herbicide options to reduce the population of broad-leafed weeds in wheat and barley crops, and likewise, many herbicides can remove grass weeds from legume crops.

4.11 Herbicide resistance

In Australia and other parts of the world, the continuous use of particular groups of herbicides has allowed populations of weeds to develop resistance to these herbicides. In some cases, some weeds have developed resistance to multiple groups of herbicides. The widespread adoption of ZT and increased reliance on herbicides has been blamed for this resistance by some commentators.

While herbicide resistance complicates weed management under ZT, researchers and farmers have developed ways to manage resistant weeds in CA systems such as crop and pasture rotation, delayed sowing, use of alternative herbicide groups, and weed seed collection and destruction. In some extreme cases, farmers have used strategic tillage to help control resistance weeds. Avoiding the long-term reliance on one herbicide or one type of herbicide, and rotating chemical groups from one season to the next, helps prevent the development of herbicide resistance.

The use of herbicides in the Middle East is much lower than Australia, so the risk of herbicide resistance is less. However, if herbicide use increases with the adoption of ZT in the Middle East, especially the use of a narrow range of herbicides, the development of weed resistance is possible. So CA farmers should be aware of this possibility.

4.2 Disease Management

As mentioned previously, some elements of CA can encourage some diseases. For example, the elimination of tillage can increase the incidence of some root diseases, such as Rhizoctonia Root Rot, while the retention of crop residues may enhance other leaf diseases. However, other diseases may be suppressed by CA systems. For example, some soil borne leaf diseases are suppressed when thick crop residues prevent the spread of spores by soil splash. The increased row spacing with ZT can help improve aeration and reduce humidity within the crop canopy, and this may reduce the incidence of some leaf diseases, such as Leaf Rust.

The integration of many disease management techniques including crop rotation, strategic use of fungicides, good crop hygiene, and genetic resistance can be used to effectively control most diseases in CA systems. In long-term experiments in Syria, no major effects of ZT and crop residue retention were found on disease incidence, apart from Ascochyta Blight in chickpea which was more widespread but not more severe in the ZT than CT plots (Fig. 41). Ascochyta can be managed effectively through a combination of delayed sowing, genetic resistance, and fungicide applications.

Figure 41. Ascochyta Blight in chickpea is favored by the retention of chickpea residues.

4.3 Management of insects and other pests

As with weeds and diseases, the incidence of insect and other pests may be increased or decreased under CA systems, and integrated management packages combining several methods, not just a reliance on chemical control, work best. In some cases, the increased crop diversity and reduced tillage in CA systems encourage the prevalence and activity of natural predators to keep insect pests at low levels.

Many insecticides are costly and are highly toxic to humans and other animals. So they should be used only when necessary. With any weed, disease or pest, it is valuable to have estimates of the 'critical thresholds', which are the population densities above which there is likely to be a significant impact on yield warranting an urgent control measure, usually a chemical spray.

For example, if the density of a Sunn Pest (*Eurygaster integriceps*, Fig. 42) is above 1-2 adults or 8-9 nymphs per m^2, then these are likely to limit cereal yields. Without these thresholds, farmers may either spray at the first sign of a pest even though the population may be small and damage may be insignificant, or more likely, they will wait thinking the levels are minor, during which time the population explodes causing massive crop damage.

Figure 42. Sunn Pest (*Eurygaster integriceps*) a pest of cereal crops in the Middle East.

Be aware that rodents prefer undisturbed soils covered by crop residues. If fields infested with rodents are cultivated, they will flee to nearby ZT fields, especially if the field has a thick cover of stubble and straw. This is a particular problem for small ZT demonstrations surrounded by cultivated fields with high rodent populations. Rodents can be managed with a chemical baiting program and by encouraging natural predators like owls with the installation of suitable nesting boxes. In some parts of Australia, slugs and snails are encouraged by the presence of thick crop residues.

5.0 CA in orchards and alley cropping

Orchards are a common component of landscapes in the Middle East, with the production of fruits in medium to high rainfall areas, and olives and nuts in dry areas. Orchards are often planted in areas with steep slopes where cropping is not possible which makes them particularly prone to soil erosion. Multiple tillage operations are traditionally used to control weeds, in some cases up to seven or more times per year. However, tillage also causes moisture loss and leaves the soil prone to erosion, especially water erosion on fields with high slope.

In many countries the principles of CA are often used to effectively produce crops in between the trees of orchards and olive groves. Tillage is replaced by herbicide applications to manage weeds, and/or grazing. Forage legumes and/or other crops are grown using CA between the rows of trees to protect the soil from erosion, provide nitrogen inputs into the system, and produce an economically valuable product to supplement the income from the trees.

We believe there is considerable potential for the use of intercropping CA within orchards in the Middle East and initial demonstrations have been set-up in Syria, Jordan and Palestine in recent years, mainly among olive groves (Fig. 43). Likewise, CA crops can be easily produced between salt and/or drought tolerant trees, shrubs and cactus alleys in low rainfall areas. This type of alley cropping is compatible with many water harvesting or micro-catchment techniques (Fig. 44).

Figure 43: CA intercropping between olives in Syria (left) and Palestine (right).

Pure stands of forage legumes or mixes with barley are either directly grazed by livestock, harvested for hay or forage production during spring, or directly grazed after maturity. This reduces the pressure on the residues from broad-acre crops so they can be used for soil cover. Some forage legume species such as clovers or medics are capable of setting seed and self-regenerating without the need to plant them every year.

Fig. 44. Basins were constructed in this olive orchard in Jordan (left) to harvest water before CA intercropping was instigated - the field slopes downward from left to right. The second irrigated orchard in Afrin Syria (right) was kept uncultivated and weeds controlled with herbicides.

In many cases the production of the intercrop has no negative impact on the tree production, and in the long-term the effects tend to be positive if erosion is reduced and soil fertility improves over time. Where trees are on narrow spacings (less than 6-8m) the competition between the trees and the CA crop may be significant. Ideally the winter rainfed crops will not compete with the period of tree production and harvest.

6.0 CA under irrigated systems

Experience in Syria, Iraq and elsewhere has shown a big potential for CA in medium to low rainfall dryland conditions due to effective moisture conservation and improved water use efficiency. But CA can be implemented under all agro-ecosystems, including high rainfall and irrigated conditions. Many farmers in Syria and Iraq have successfully implemented ZT on fields using pivot, sprinkler and drip irrigation methods.

The initial benefits of CA under irrigation mainly come from input savings rather than production increases since the availability of moisture is not a constraint. It is commonly observed that biomass and grain yield production in irrigated crops is initially similar under ZT or conventionally tilled fields, or in some cases, crop growth may be less as farmers struggle with the initial challenges of ZT, heavy crop residues and more diverse rotations. It usually takes several years under CA for farmers to come to terms with these challenges and for the improvements in soil fertility to boost crop productivity. As with rainfed crops, gradual adoption of CA, starting with ZT, is normally wise.

The main input saved under CA is fuel. Tillage operations are eliminated, and other fuel and water savings might also be made from reduced amounts of irrigation. With ZT and retention of crop residues, water infiltration into the soil is increased and evaporation is decreased. This applies to winter crops receiving supplementary irrigation and secondary summer crops, grown after the winter crop, and could help conserve ground and river water resources for the Middle East.

Figure 45: An irrigated ZT sorghum crop (secondary crop after wheat) at Aleppo (left), and ZT maize (secondary crop) under pivot irrigation in SYLICO, Syria 2011 (right).

In the Middle East, irrigated secondary crops are traditionally grown immediately after winter crops. The farmer usually needs three to four weeks to collect, graze or burn the residues from the winter crop, and prepares the soil with three cultivations and one or two irrigations to enable planting of the summer crop usually in July (Fig. 46). Because of this delay in planting the summer crops, maturity and harvest is delayed until November when there is a risk of early autumn frosts.

Direct ZT planting of secondary summer crops immediately after harvesting the winter crops in June could save the cost three cultivations and allow one month earlier planting. More timely sowing is a major incentive for ZT in South Asia where two or more crops are grown each year.

Figure 46: Land preparation for irrigated summer crops in Aleppo, including grazing by small ruminant (in the background), burning straw and flood irrigation to get the soil ready for tillage and planting.

CA can be implemented under sprinkler, drip or pivot irrigation systems using the same ZT seeders developed for rainfed crops (Fig. 47). Basin flood irrigation (Fig 47 right), with its ridges around the boarder of each basin or plot, is not compatible with ZT planting and minimal soil disturbance. This irrigation method is generally inefficient in its water use compared to other methods, and a change in irrigation method should be considered.

Figure 47: Sprinkler, pivot and drip irrigation can easily fit with ZT planting, however basin flood irrigation (bottom right) is not compatible.

With furrow irrigation, CA can be implemented with minimal soil disturbance using a raised-bed ZT planting system (Fig. 48). Permanent beds and furrows are set out in the field, and retained year after year. The furrows are reshaped each year by the seeder, which sows two or more ZT rows on the raised bed, usually with retained residues. This technique was developed for furrow irrigated crops in South America, Central and South Asia, Egypt and other parts of the world, where savings in water and fuel, and increases in soil fertility and yields have been significant.

Recommendation: CA can be implemented under sprinkler, drip or pivot irrigation systems using the same ZT seeders developed for rainfed crops. For furrow irrigation, permanent raised beds are recommended.

Figure 48: ZT raised-bed wheat fields using furrow irrigation in Uzbekistan (planting after cotton, left), and in Egypt (right).

7.0 Promoting adoption of CA

In Morocco CA was first investigated by researchers in the late 1980's, and proving successful at increasing sustainable production, a program of field demonstrations was instigated to promote adoption. About 30 years later, CA only covers around 6,000 ha in Morocco with only a small proportion of unassisted adoption. Similar research also occurred in Turkey during the 1990s where adoption of ZT was negligible until recent years. If the benefits of CA were significant, then why wasn't the technology adopted by farmers?

A few large farmers in these countries did initially adopt CA because of their financial ability to purchase large ZT seeders imported from America and Europe, and they had greater incentives to save on fuel and input expenses because of their big acreages. In contrast, there was virtually no adoption by the majority of farmers who owned relatively small to medium areas of land, mainly because the imported ZT seeders used were too large, heavy and expensive.

Another factor in the poor adoption was the way the technology was demonstrated and presented to farmers. In some cases, farmers were not closely involved in on-farm demonstrations and at field days and other extension activities they were often told they must adopt all three pillars to benefit from CA.

In contrast the early projects in Morocco and Turkey, the ICARDA Iraq CA project mentioned in sections 1.0 and 2.61 was effective at promoting the adoption of ZT and early sowing in Iraq and Syria. There are pertinent lessons from this project that can be applied in other parts of the Middle East and elsewhere, especially the development of simple and cost-effective ZT seeders, and the flexible participatory extension approach.

7.1 Availability of ZT seeders

Around the Middle East there are many ZT seeders which were imported by development agencies ten or twenty years ago, but most have been sitting idle on research stations and farms, either because: they were too complex, large and heavy; or technical staff were not trained appropriately in their set-up, calibration or operation; or spare parts were not easily available. There is little point in trying to promote CA to farmers if they do not have access to suitable ZT seeders, and know how to use and maintain them accordingly.

The ZT seeders should be appropriate for the size of fields, the capacity of available tractors, and should be made available at an affordable price. The promotion of ZT seeders should take into account the existing models of farmer access to conventional mechanization such as via contractors and cooperatives. Appropriate ZT seeders can be imported if they are available outside the country, or preferably made by local workshops if suitable specifications and acceptable quality can be achieved. In addition to generating employment for rural communities, local workshops also provide easy access to spare parts for maintenance and repairs. Alternatively, some conventional seeders can be easily converted to ZT at a fraction of the cost as discussed in section 3.4.

It is important to understand the range of cropping practices and machinery used in a region so that appropriate ZT seeders are developed. This can be done through formal or informal surveys of farmers. The sorts of data collated in this survey could include machinery information (e.g. the power of available tractors, seeder widths, and whether they are trailed or mounted via a three-point linkage, availability of hydraulic ram connections) as well as details of crop management (e.g. existing tillage and seeding operations, soil types, rainfall, crop rotations, time of sowing, seed rates, seed depth, row spacing, use of fertilizer and pesticides, and residue management). This information will help in the development of suitable ZT seeders and other CA practices.

In the ICARDA Iraq CA project, Australian engineering and agronomy expertise were used to enhance the skills and knowledge of machinery manufacturers and agricultural engineers at universities and ministries of agriculture to help facilitate the local manufacture of ZT seeders in several countries. Technical and practical training programs were conducted over a period of three years (Fig. 49), and following feedback from farmers and contractors various prototypes of ZT seeders were reviewed and improved in a repetitive process.

Figure 49. A field evaluation of various ZT seeders at ICARDA's Tel Hadya Research Station in Syria.

The main aim of the machinery training program was to improve the mechanical design and construction skills of the manufacturers especially for ZT conditions. Seeder design considerations for ZT such as those discussed in section 3.0 were reviewed in detail. Methods of converting conventional seeders to ZT were also part of the training, especially in Iraq where the manufacturing industry was less advanced (Fig. 50).

Figure 50. A Nardi seeder converted to ZT, including press wheels manufactured in Mosul Iraq.

Many the manufacturers and engineers the project worked with had farming backgrounds, especially those from regional villages. Others did not have a good understanding of cropping practices, nor close relationships with their farmer customers, and were often replicating seeder designs that were 30-40 years old without any understanding of more contemporary design improvements, nor any consideration of how to make them more efficient. These manufactures benefitted greatly from an improved knowledge of crop agronomy, seeder function and seeding system technologies, and where possible they were encouraged to work more closely with farmer groups and their customers to facilitate feedback and ongoing seeder improvements.

Small groups of manufacturers and engineers also benefited from study tours to Australia and Turkey, where the manufacturing industries were more advanced and farm machinery fairs were held. During such tours they were exposed to innovative seeder ideas and designs, especially in Australia, and the manufacturers were also able to arrange the supply of key parts and materials. In almost all cases, the feedback and response from such tours and the ZT seeder training programs was exceedingly positive.

As discussed in section 3.5, the machinery activities of the project contributed greatly to the supply of appropriate ZT seeders to farmers in Syria and Iraq and also influenced manufacturers in Jordan, Turkey and Iran. While the initial seeders sometimes lacked the sophistication and quality of imported ZT seeders, they were affordable and did an effective job at establishing crops under ZT tillage, some into moderate to high amounts of crop residues.

Many of the seeder manufacturers became key players in the participatory extension groups that were established in Syria and Iraq, and they were active in promoting the ZT technology because it benefited their business and the profitability of their farmer customers. Some seeders were displayed at agricultural exhibitions and fairs to help raise awareness and interest in ZT (Figure 51). Even in areas of civil conflict in Syria and Iraq, manufacturing is still ongoing.

Figure 51. Three ZT seeders were transported to Damascus for an agricultural exhibition in 2008.

Many small-scale farmers in the Middle East do not own their own tractor and seeder, and borrow or rent such equipment from larger farmers or contractors. In these cases, it will be necessary to convince the providers of these machinery services about the benefits of CA as well as the small farmers themselves.

This can be difficult with contractors because many make part of their income from providing tillage operations. These contractors need to develop a suitable business model whereby they charge more for ZT seeding compared to conventional seeding to compensate them for the lost income with the elimination of plowing. Of course overall they will benefit from lower fuel and labor costs with ZT. Importantly, the adoption of ZT and CA will enhance the profitability of their farmer customers, leading to repeat and new customers into the future.

Recommendation: Farmers need access to ZT seeders that are appropriate for the size of their fields, the capacity of available tractors, and should be supplied at an affordable price. These can be manufactured locally, imported, or conventional seeders can be converted to ZT.

7.2 Participatory extension approaches

In many parts of the world where CA has been successfully adopted, farmers and farmer-led organizations took the lead in developing and promoting ZT technology in collaboration with researchers and extension specialists, input suppliers and machinery manufacturers. In Australia, no-tillage and other farmer groups were established in each state – a list of the no-tillage groups and their websites is presented in section 10.0.

As part of the ICARDA project in Syria and Iraq, Australian experts in participatory approaches were engaged to deliver training programs to farm advisers who were then encouraged to go back to their regions and test the new approach. Unlike the traditional extension model where the researcher develops a new technology and hands this over to an extension workers to convince farmers to adopt the technology, participatory approaches encourage all stakeholders to work together as a group to identify issues, discuss potential solutions and evaluate these on farm. These participatory groups are sometimes called innovation platforms.

Participatory groups encourage direct feedback between researcher, extension specialists and farmers, and all other stakeholders in the community while facilitating greater mutual understanding and respect. Many researchers and farm advisers need to realize that they can learn much from farmers, and this will help them to develop new technologies that will benefit the farming systems in their region. This approach is particularly important for complex technologies like CA that require modification and fine-tuning to each region or situation.

Interaction between stakeholders was rarely equal. In fact the relationship between farmers and manufacturers was usually the backbone of groups and was most critical to their success, especially in the development of suitable ZT seeders which is so important for CA. The relationships between farmers and local manufacturers persisted when civil conflict disrupted the activities of researchers and extension specialists in Syria and Iraq, and helped promote on-going adoption in difficult circumstances.

Farmer groups were established in Iraq and Syria to discuss CA and to evaluate useful elements of the conservation cropping package (see Table 2) on farms. These groups not only involved farmers, researchers and extension specialists, but included service and input providers, machinery manufacturers, local government staff, and other private and non-government organizations such as the Agha Khan foundation and regional institutions such as the Arab Center for Studies of Arid Zones and Dry Lands.

Figure 52. An illustration of the participatory extension groups investigating CA in Syria showing effective interaction between all stakeholders, especially farmers and manufacturers.

Within each group a ZT seeder (either manufactured or converted locally) was made available to farmers interested in testing it without providing any payment or other incentives to the farmer, other than use of the seeder free of charge and technical advice. Some farmers were anxious about damaging the seeder, so they were assured that they would not be held responsible for any damage.

The fact that there were no incentives provided to the farmers who participated in the testing program, and that they were expected to supply their own seed, fertilizer, tractor and fuel, and move the seeder to the next farmer, was seldom questioned. This was not a limitation for innovative farmers who were keen to increase the long-term profitability of their businesses, and could see the prospects of the technology to increase yields, decrease costs, and improve their soil fertility. All groups appointed an honorary group facilitator to coordinate the testing program and arrange repairs and maintenance of the seeder if needed.

Recommendation: Participatory extension approaches where farmers, machinery manufacturers, researchers, extension specialists and other stakeholders work as a group to adapt a new technology to local conditions, work best in promoting complex technologies like CA.

Figure 53. A group of farmers, researchers and extension specialists inspect ZT seeders at field day in Salamiyah, Syria.

Direct communication from farmer to farmer was supported and most farmers enthusiastically shared the lessons they learnt with others at field days and group meetings. In many cases researchers and extension specialists only provided input when specifically asked which demonstrated that the groups were controlled by farmers. Some activities were publicized by national television channels and other media outlets.

The activities of the groups proved popular among all members, and highly effective in raising awareness, experience and adoption of ZT. The number of participants in the program and the formation of new groups grew rapidly each year as the benefits of ZT and early sowing became more widely known. The participatory aspect of this program was critical to its success as it gave farmers ownership of the groups, the ZT testing program, and hands-on experience with ZT seeder operation, early planting of crops and reduced seed rates in their own fields.

Leading pioneer farmers emerged from many groups. These leaders who were often among the first adopters of ZT, showed much passion and commitment to helping other farmers and spent large amounts of time and effort working with other stakeholders, especially seeder manufacturers to promote ZT technology within their region. These farmers were usually relatively large and financially capable of purchasing a ZT seeder, and were excellent farm managers, making them admired and highly respected among the community. They often lent their ZT seeder to relatives and neighbors.

Figure 54: Extentionist Mr. A. R. Omar (left) coordinated 86 ZT evaluations in Maara, Syria in 2011, and is standing in front a conventional field next to a ZT field sown early. Agronomist, pesticide dealer, and farmer group leader Mr. Bakr Bakki (right) with his son near Ain Al-Arab (Kobani), Syria, is standing in front of traditional late planting and a ZT field sown early.

Some of these leading farmers, proud of their achievements and keen to spread the benefits of ZT technology, independently organized and funded their own field days (Fig. 55). In some cases large influential farmers who sow fields owned by many smaller farmers was invited to participate in the ZT seeder test. This strategy was a successful way to expose a large number of farmers to the technology. An important event in Iraq was the formal recognition of the “Mosul Society of Conservative Agriculture”, a group of farmers and scientists who encourage and support CA development and education in Ninevah.

Figure 55. Pioneer farmer, Mr. Sinan Al-Jalili, discuss the benefits of ZT for his farming business at a field day at his farm near Mosul Iraq.

7.3 CA demonstrations and farmer incentives

In other less successful projects, CA demonstrations were conducted on-farm whereby the farmers were much less involved than the approach described above in Syria and Iraq. In these CA demonstrations technical staff from a nearby research station managed the test area including seeding, spraying, spreading fertilizer, sampling and harvest, supplying all inputs including machinery. In some cases, the farmer was also paid a fee for the use of his land. This approach is generally less effective because the farmer is only learning by observing and is not learning by doing, and often takes less ownership and interest in the evaluation.

In some regions of the Middle East, land ownership has become highly fragmented and many farms are too small to support a family. In such cases landowners are forced to seek other jobs and sources of income. If agriculture is not their main source of income, then landowners are usually less interested in improving the profitability of their farming operations, especially if this involves major changes to their traditional methods. These types of farmers are usually less inclined to participate in a testing program unless they are provided with incentives.

Cash and other incentives may encourage some farmers to join demonstration activities. However, once the incentives stop, the farmers usually returns to their old practices and little real adoption occurs. In recent years the Turkish government provided farmers with a 50 percent discount when they purchased ZT seeders in an attempt to boost adoption, but no other information or training on CA was provided. Given this sizeable incentive, many farmers bought ZT seeders. However, most of these farmers still plow their fields before sowing because they are not aware of the benefits of ZT and have problems with weed control.

Farmer incentives or subsidies for adopting CA should be implemented cautiously because subsidies often create inefficiencies and unexpected negative impacts. For example, as discussed in section 2.3, government incentives for the production of wheat can have detrimental effects on other crops, reducing the overall efficiency of the farming system. Ideally farmers will be keen to improve the long-term profitability of their farms, the immediate and direct benefits of ZT and early sowing will be enough incentive for farmers to try the technology, and incentives can be avoided completely.

Some non-government organizations have an interest in developing rural communities by promoting technologies which enhance farmers' productivity and incomes. CA is capable of achieving this while also reducing any negative environmental impacts of cropping. The donation or micro-financing of ZT seeders for poor farming communities especially in marginal areas could result in favorable outcomes, provided suitable training and a participatory approach is employed. The Agha Khan Foundation, a partner in the project's participatory ZT development and extension program, had a successful experience with this approach in Salamiyah Syria.

Recommendation: On-farm testing and CA demonstrations are an important way for farmers to see the benefits of CA first hand. In Syria and Iraq farmer payments or other incentives to conduct demonstrations proved unnecessary as the technology was of great interest, relevance and benefit for all stakeholders.

7.4 Training and education

As we have said several times in this publication, the general crop management skills of many Middle Eastern farmers requires improvement, and the full benefits of CA require a good knowledge of machinery, agronomy, pest management and general farm organization.

Certainly, farmers who have access to micro-financed, discounted or free ZT seeders should receive a well-structured and comprehensive CA training program to ensure they get the most from the technology. Training programs can be coordinated through existing participatory farmer groups or be a catalyst for the formation of new groups in a region.

The skills and knowledge of other participants in the participatory groups and the wider community may also need to be enhanced to effectively develop and promote CA systems for a local area. In particular, extension specialists need to have a good understanding of CA principles and practices, including ZT seeders, and participatory approaches to extension. They should also develop a network of technical specialists to help provide advice in range of topics e.g. machinery, pest management, crop nutrition, etc.

Figure 56. Dr. Abdulsattar Alrijabo from University of Mosul discusses ZT sowing and crop management at a farmer field day in Ninevah, Iraq.

In Ninevah Iraq, University of Mosul staff undertook a program to educate school children in rural areas about CA and the benefits of ZT (Fig. 57). Children were aware of tillage and other farm operations and were keen to learn about new cropping methods that saved fuel and time. High quality fact sheets, posters and other extension material help increase awareness and knowledge of CA (Fig. 58). All these initiatives help people overcome the deeply engrained mindset that tillage is an essential part of farming and other misperceptions about CA.

Figure 57. Mrs. Asma Al Hafiz, University of Mosul speaks to rural school children about the benefits of ZT.

Recommendation: The full benefits of CA require a good knowledge of machinery, agronomy, pest management and general farm organization. If these are lacking, then suitable training and education of farmers and other stakeholders may be required.

Figure 58. A poster developed to promote awareness of CA in Iraq.

7.5 Field Days

Field days are a critical activity for any extension programs as they allow a large number of diverse groups to observe, learn and discuss a new technology. In a survey of Syrian farmers who adopted ZT, attendance at a field days or participation in a CA farmer group was the most important factor influencing adoption. It is important that field days are well planned and organized.

Traditionally field days are conducted in mid to late spring when crops are looking their best. Given the importance of ZT sowing for CA, field days demonstrating conventional and ZT planting in autumn can be highly beneficial. Autumn field days can be followed up with subsequent field days after crop establishment, spring and pre-harvest, as many farmers may be keen to monitor crop performance throughout the season. This will provide a chance to discuss various elements of crop management, including the monitoring of weeds, diseases and pests. It is a good idea to have a ZT seeder present at each field day, for newcomers to understand the technology.

Figure 59: Scenes from a pre-harvest CA field days with about 350 participants at Qamishly and Jarjanaz, Syria 2011.

The logistics for the field day will partly depend upon the number of participants. Large groups are slow and cumbersome to manage, but can get an important message across to many people at one time. Smaller groups of 8-16 people are better more detailed training activities or discussion groups. For large field days, it might be beneficial to break the crowd into a number of smaller groups if there are two or more separate inspections or activities are planned.

Most field days benefit from the guidance of a leader to coordinate the activities and help keep the group together and attentive. Without this guidance some people may start to straggle and split off into smaller groups with multiple discussions occurring at the same time, or one person may dominate the discussion. In many situations it is good to involve the audience. For example, you might ask them to rate the vigor of two different crops or a range of test plots, or invite them to suggest solutions to problems. But this should be done in a structured way through the leader.

It is important to allow the farmer who conducted a test to speak freely about what was done, what worked well, what needs improvement and possible solutions. Farmers are more likely to listen to other successful farmers than researchers and other technical experts.

Some important logistical considerations for field days include the need for transport, water and food, shade, bathroom, and a public address system. These should be organized and tested well ahead of the field day – a major delay or problem with any of these can have detrimental effects and participants may lose interest quickly.

Figure 60. A farmer field day conducted in autumn at Al Shaikhan, Iraq – the host farmer is front and center.

Recommendation: Field days allow a large number of diverse groups to observe, learn and discuss a new technology with other farmers and other stakeholders.

8.0 CA misperceptions and challenges

There are a number of misperceptions about CA in the Middle East that are often held by farmers and others when they are first informed about the concept of CA. Some of these misperceptions originate from people outside the region who have dogmatic and rigid views on what is CA, and how it should be implemented. We have presented these misperceptions below as coming from farmers (i.e. I was told ….), but these are sometimes proliferated by academics, farm advisers and researchers with inflexible mind-sets.

These misperceptions will be dispelled as more people become aware of CA, and see it successfully implemented in the Middle East.

8.1 CA won't work in my conditions

Many people who don't realize how widely CA has been adopted around the world believe CA won't work on their soil or farming system, especially ZT. The fact that CA is being successfully used in a wide range of climates, crops, soils and farming systems means that it can be adapted to work in all areas where crops are grown, and in almost all crops, provided a flexible approach is taken.

Part of this misperception is the belief that crops cannot be successfully planted and established without tillage, especially on hard or stony soils. While some soils may be problematic when ZT is initially implemented, the facts show that crops can be sown efficiently on all soil types with appropriately designed and operated ZT seeders. In CA systems, soils become soft and friable as organic matter increases and soil structure improves over time. In Australia, CA is implemented on a wide array of soils, from some of the sandiest acid soils in the world, to heavy alkaline clays.

CA is often promoted as a technology particularly suited to dry areas and as a way of combating drought, but this does not mean it is not applicable in medium and high rainfall zones, or under irrigation. There is evidence from southern and eastern Africa indicating that the benefits of CA are less in high rainfall areas where waterlogging occurs because of increased rainfall infiltration. But this has not been observed in the Middle East or North Africa. Certainly, soil cover and ZT decrease the risk of soil erosion in high rainfall areas with high slope.

8.2 I was told I must use a disc ZT seeder to eliminate soil disturbance

It is often believed that almost no disturbance of the soil and crop residue is best, and that this can only be achieved with the use of disc ZT seeders which cut the narrowest of slots in the soil without dislodging residues. While keeping the residue undisturbed is best-practice, there is little evidence to suggest that ZT disc seeders which disturb a very small minority of the soil surface provide superior crop performance to ZT tine seeders which disturb more of soil.

Technically, some disc seeders can cause high soil disturbance depending upon their design blade, set-up and operation (e.g. triple disc seeders on narrow row spacing operated at depth and high seed). In comparison, some tine seeders cause much less soil disturbance (e.g. those with narrow openers on wide row spacing operated at shallow depth and low speed). As discussed in section 3.31, disc seeders have some well documented limitations, particularly in degraded soils commonly found when transitioning to CA. Tine seeders are arguably more suitable for small farmers in developing countries because of their simplicity, light-weight, low cost, and ability to penetrate hard soils and operate more easily in wet clay and/or stony soils.

As we discussed earlier, there is a large array of seeders which produce reduced or minimum soil disturbance, and researchers and farmers are often confused about which are the best seeder features for their circumstances. Often, farmers and researchers use a ZT seeder which is either not suitable for the conditions and/or incorrectly set-up and calibrated, and hence, poor establishment and crop growth results. In the absence of better knowledge, they conclude that ZT does not work well.

Hopefully the discussion in section 3.0 helps reduce this confusion, but in general, much more attention needs to be paid to ZT seeder design and operation, and the knowledge of all stakeholders can be improved. In almost every case, ZT seeders need to be fine-tuned to local conditions to get the best performance.

Figure 61. Pioneer farmer and engineer, Mr. Sinan Al-Jalili, discusses point design at a farmer field day near Mosul Iraq.

8.3 I was told I must not graze my crop residues

Some researchers and extension specialists believe that soil cover is a critical part of CA, and without it farmers will not benefit from the adoption of the other principles. While there is evidence to support this in eastern and southern Africa, this does not hold true in the Middle East. Significant benefits were recorded by farmers in Syria and Iraq solely with ZT and early sowing, even when crop residues were heavily grazed and crop rotation was dominated by cereals (Fig. 61).

As discussed in section 2.22, farmers who graze their crop stubbles should not be criticized when they are getting a high and stable economic return for this practice which is maintaining their farming livelihood. There is also evidence to suggest that light grazing of residues may provide a useful benefit to livestock while the remaining residues help protect the soil from erosion and maintain soil fertility. While the trade-offs between grazing and retaining crop residue are the topic of ongoing research (including the integration of forage crops into existing systems), allowing farmers to maintain livestock grazing during the transition to CA enables a much more attractive and low risks package, without challenging the economic stability of their existing crop-livestock systems.

Figure 62. Mr. Sobhi Al Abdalla from Maara, Syria seeded ZT lentil after the cereal residues were completely grazed (middle). The ZT field produced 2.1 t/ha (right front), compared to the adjacent conventional field (right behind) which yielded 1.6 t/ha.

8.4 Legumes and other crops are more work and don't yield like cereals

Many farmers complain that legume and other alternative crops require more work and their yields are lower compared to cereals. While this is often true, they should consider the economic returns from their crop rotations as a whole production system.

By alternating cereals with other crops, this boosts the performance of cereals through nitrogen fixation and reduced fertilizer requirements in the case of legumes, provides an opportunity to better manage weeds (especially grasses), diseases and pests, and diversifies production, thereby reducing the risk of price fluctuations. While the yield of these alternative crops is usually lower than cereals, this is often offset by higher prices, although production costs (e.g. the need for hand harvesting) can also penalize legume and other crops. Even growing a legume or alternative crop in between two or three cereals crops is better than continuous cereal production. More than ever, a farming systems approach is required to successfully conduct a CA production system.

As discussed in section 2.3, there is much that needs to be done to develop and promote more profitable legumes and alternative crops. The development of improved taller varieties and crop management practices will enable machine harvesting and increase yields. Government policies that encourage wheat production need reviewing, and the general crop management skills of many farmers needs to be improved. Managing two or more different types of crops adds complexity to farm management and can be hard work, but some farmers manage these issues effectively because they can see how crop rotation is important for the long-term profitability of their farms.

8.5 Fallow gives the soil 'a rest' and boosts the yields of following crops

As discussed in section 2.3, an effective fallow can conserve moisture from one season to the next and benefit following crops in low rainfall environments. However, the benefits are inconsistent, and often much of the soil moisture is lost through evaporation during the long hot and dry summers of the Middle East. Most studies show that on average the extra yield of the crop following the fallow does not compensate for the total yield that would have been produced by growing a crop every year instead of the fallow. Likewise, the increases in soil fertility during fallow phases are typically small.

Instead of using a fallow phase, farmers in low rainfall areas are better off planting a crop every year. The risk of crop failure due to drought is decreased in CA systems because soil evaporation is reduced, and rainfall infiltration and water-use efficiency are increased. So this should give farmers confidence to replace fallow with a CA crop, ideally a low-cost food or forage legume.

8.6 Weeds or other pests will take over my fields if I don't plow

This misperception is not surprising when you consider that some older farmers may have plowed their fields multiple times for 30 years or more, mainly to reduce the populations of weeds and other pests. As explained in section 4.0, the population of weeds, diseases and pests usually changes when CA is implemented, but the overall burden often remains the same, especially in dry areas. Some biological species are favored by some of the CA technologies, and others are suppressed by the elimination of ZT, rotation of crops, and retaining soil cover.

Provided an integrated approach employing a range of strategies is used, weeds, diseases and pests can be managed effectively under CA systems. Good knowledge and crop management skills are required in CA, especially if new pests emerge. Rodents are a common problem under CA, especially when a ZT field is surrounded by cultivated fields.

8.7 CA needs more inputs, especially pesticides

This misperception follows on from the previous one. If the overall burden of weeds, diseases and other pests are similar, then there no greater reliance on pesticides in CA compared to conventional systems.

In most medium to low rainfall regions of the Middle East where very little grows during the hot dry summer period, weeds are rarely present at sowing if the crop is planted early i.e. close to the first autumn rains. If weeds are present before sowing, these should be killed with the application of a non-selective herbicide, so one more chemical application may be required in this case. In general, post-emergent applications of herbicides, fungicides and insecticides will be similar in CA and conventional systems.

In all cases where ZT is adopted there are significant reductions in fuel and labor costs, and also savings in seed inputs are likely. If legumes are added to the rotation, organic nitrogen can be more available, and in some cases phosphorus fertilizer can also be decreased. Under irrigation less water is often required.

8.8 ZT contradicts our knowledge and culture

Some farmers, academics and others consider tillage or seedbed preparation is a key operation for a successful crop and that ZT contradicts their agricultural culture and heritage. Farmers who don't till their fields are sometimes labelled as lazy, messy, and not serious by others. These people are often not open to change, and are difficult to argue with. But most farmers listen to other successful farmers, and the early 'ZT champion' farmers need to be supported and included in CA promotion activities. A gradual process of evidence-based assessments and empowerment with accurate information supporting a fitting alternative can soon lead to changed mindset.

Most farmers in the Middle East recognize that soils are becoming seriously degraded and crop yields are declining, especially as the weather becomes more variable. How can we expect to improve our farm productivity without trying something new? As Albert Einstein said "The definition of insanity is *doing the same thing* over and over again and expecting different results."

Many farmers appreciate that they don't just inherit their land from their fathers, but they are also its custodians for their children, and grandchildren. If they don't care for their soil and farms, their descendants will suffer.

9.0 Moving towards conservation agriculture

Conservation agriculture is a complex technology. Once given some initial information about the technology, many farmers are interested in evaluating the benefits on their own farms, but they are sometimes puzzled by where to start and what changes to their cropping practices are required.

As we have stated many times, ZT is the key to CA in the Middle East, and farmers should concentrate on this component of the technology when moving towards CA. Diverse rotations and soil cover are more difficult to implement in the Middle East, so most farmers will naturally be more interested in ZT. Once farmers are confident in using ZT, they can consider diversifying their crop rotations and then later may also be interested in evaluating the benefits of soil cover. This process towards full adoption of CA might take five or more years.

The initial testing and success of ZT will often depend on the way the farmer learned about the technology.

- If the farmer attended a planting or spring CA field day, then he/she may have been exposed to the experience and knowledge of several other farmers, seeder manufactures, researchers and extension specialists. The farmer may later approach the nearest extension specialist, seeder manufacturer or nearby farmers for more information, and he/she may like to become part of the CA working group. Access to many sources of information is usually the best way to benefit from the lessons learnt by others and ensure successful adoption.
- If the farmer sees ZT planting in neighbor's field then he/she may be interested in borrowing, converting or buying a seeder. Unless the farmer seeks information from others, which would be highly recommended, he/she only has access to the experience of that one neighbor. This is less preferable than the case above.
- Some farmers may have heard about CA or had it recommended by others without any first-hand experience through a field day or neighbor. We recommend that farmers do not implement ZT or CA before seeing the ZT crops first-hand and inspecting ZT seeders either through neighbors or field days.

Once a farmer has decided to implement ZT, they must get access to a ZT seeder either through a CA farmer group, borrowing from a neighbor, converting a conventional seeder to ZT, buying a new ZT seeder, or through a ZT seeding contractor. We recommend the following practices:

1. Stop plowing or cultivation immediately.
2. Check for a hard pan in the soil and correct this – see section 2.21.
3. If the field has a high population of weeds (as seen in the previous crop) allow these to germinate for 1-2 weeks after the first autumn

rains, and then kill them by spraying a non-selective herbicide such a glyphosate (1-1.5 L/ha of commercial product). Follow the directions on the herbicide label, but these herbicides are generally safe to apply one day before planting.

4. If weeds are not a major problem, then cereals should be planted immediately after the first autumn rains, or even before the first rains into dry soil. Lentil, faba bean, vetch and other forage legumes generally benefit from early sowing, but there is generally little need to plant chickpea before late November.
5. Use certified seeds at reasonably low rates (70 to 100 kg/ha for cereals and 100-120 kg/ha for lentil and chickpea, depending upon the mean seed weight and viability.)
6. Never spread TSP or DAP fertilizers on the soil surface at planting, but drill them together with the seeds or separated by 2-4 cm – see sections 2.45 and 2.35.
7. Use an appropriate ZT seeder, preferably a tine-type, which has been calibrated and set-up correctly – see sections 3.3-3.5.
8. Place the seeds at 5-6 cm deep for early dry seeding and 3-4 cm deep when planting into wet soil.
9. Seed at no more than 6-8 km/hr or less if the soil is stony or sticky.
10. All operations following the seeding of the ZT crop are similar to conventional crops in terms of fertilizer and pest management.

Once farmers are comfortable with ZT, they should examine their crop rotations as follows:

1. Fallow should be replaced by a crop, preferably a legume such as lentil, chickpea, vetch or faba bean.
2. Avoid continuous cereals (wheat or barley) by planting a legume, ideally every second year, or every third or fourth year.
3. Consider other crops such as cummin, coriander, Lathyrus, fenugreek (Trigonella), safflower, or spring/summer crops such as melons, or forages/pastures.

Farmers should consider improving soil cover as follows:

1. Minimize grazing of crop residues, if possible – try to leave at least 1.5 to 2.0 t/ha on the soil surface.
2. Avoid burning crop residues.
3. If the amount of residue is beyond the capacity of the available seeder, this may be reduced by baling, chopping, mowing or slashing, or managed grazing – see section 3.33.
4. At harvest try to leave as much cereal residue standing, by cutting just below the lowest heads, and spread the chaff, rather than leaving it is narrow trails. Many harvesters come with optional straw spreaders.

10.0 More information

More information on CA can be sourced from the following websites:

ICARDA	http://www.icarda.org/conservation-agriculture/teaser
Food and Agriculture Organization	http://www.fao.org/3/a-i4066e.pdf
Western Australian NT Farmers Association	www.wantfa.com.au
South Australian NT Farmers Association	www.santfa.com.au
Victorian NT Farmers Association	www.vicnotill.com.au
CA and No-till Farmers Association	www.canfa.com.au
Conservation Farmers Incorporated	www.cfi.org.au

Global Community of Practice for Conservation Agriculture - you can subscribe to their newsletter at https://listserv.fao.org/cgi-bin/wa or send an e-mail to: listserv@listserv.fao.org

Rama Agricultural Equipment MFG can be contacted at:

P.O. Box 830327, Amman 11183 JORDAN

+962 6 4398012 or +962 5 3826007

thaer.nimer@ramajordan.com

Youtube video of interview with Syrian collaborator Dr. Basima Barhoum GCSAR on CA: http://www.youtube.com/watch?v=fMFdSUy4nOU&feature=youtube_gdata_player

Youtube video of interview with Bill Crabtree from Australia on CA: https://www.youtube.com/watch?v=t9zFLNNH_sY&x-yt-cl=84924572&x-yt-ts=1422411861

Youtube video from Tim Neale, PrecisionAgriculture Australia on CA. This is the 1st of a 6 part series and you find other 5 parts on Youtube: https://www.youtube.com/watch?v=G_JLwX2A-to

Youtube videos demonstrating differences in between runoff in ZT and conventional soils in US: https://mail.google.com/mail/u/0/?shva=1#inbox

https://www.youtube.com/watch?v=I_7d0h2bSoY

10.1 References and further reading

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About the Cooperating Organizations

Australian Government

Australian Centre for International Agricultural Research

The Australian Centre for International Agricultural Research (ACIAR) is a statutory authority that operates as part of the Australian government aid program. The Centre encourages Australia's agricultural scientists to use their skills for the benefit of developing countries and Australia. ACIAR funds research projects that are developed within a framework reflecting the priorities of Australia's aid program and national research strengths, together with the agricultural research and development priorities of partner countries.

ICARDA

Science for Better Livelihoods in Dry Areas

Established in 1977, ICARDA is one of the 15 centers supported by the CGIAR. ICARDA's mission is to improve the livelihoods of the resource- poor in dry areas through research and partnerships dedicated to achieving sustainable increases in agricultural productivity and income, while ensuring efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on- farm water use efficiency, rangeland and small ruminant production. In Central Asia, West Asia, South Asia, and North Africa regions, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR

CGIAR is a global agriculture research partnership dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations and the private sector. www.cgiar.org