3 ANALYSIS OF VARIATION IN PRODUCTIVITY

It is apparent above that WUFMAS has been able to demonstrate significant improvement in water productivity. This is more due to greater yield being produced on demonstration fields without disproportionate cost, than to the improved efficiency of water use, although both factors contributed. The question arises of what the managers of the demonstration fields have done in order to achieve this result.

3.1 Yield Factors

Agriculture is a complex biological environment that does not lend itself easily to mathematical analysis. Most of the apparently simple factors of production are in fact complex in the manner in which they may affect yield. Leaving aside the complexities of physiology, for example the production of greater plant growth without a corresponding yield benefit, the timing and manner of application of the factor often is more important in influencing yield than the rate used.

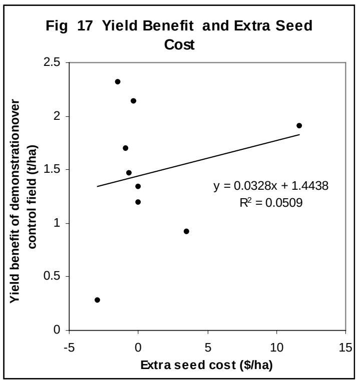
There are two approaches to analysis of yield response:

- Use data of all 18 fields,
- Calculate the difference between the demonstration field and the control and use only 9 farm values.

The first method would attract variation in yield caused by differences in soil and climate factors between the farms that might obscure the relationship with the production factor. The second method would partially eliminate extraneous variables but with fewer samples, requires closer fit in order to achieve statistical significance. Both approaches were applied to the WUFMAS data leading to much the same conclusions, so for simplicity, it is the second that is discussed here.

3.1.1 Seed

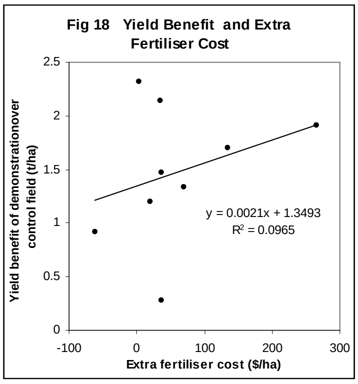
The demonstration fields on average had strikingly greater return to seed than the control fields (see above). Figure 17 shows that the yield response was unrelated to the extra cost of seed used in the demonstration fields.

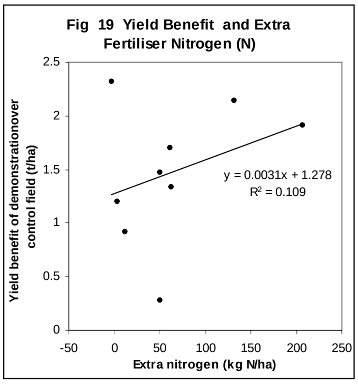


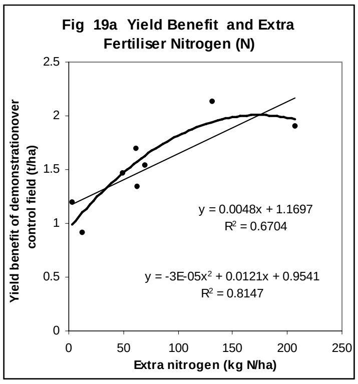
3.1.2 Fertilisers

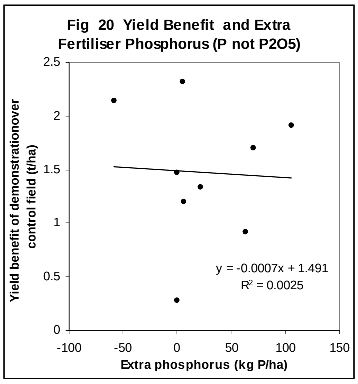
Figure 18 plots the yield response against the cost of the extra fertiliser used on the demonstration fields. There is no apparent influence of fertiliser on yield, but it should be noted that the largest and smallest response were both exceptional cases. The largest response was at Farm 18 (Turkmenistan) where the control field was planted very late at the end of May. The smallest response was at Farm 09 (Kyrgizstan) where the demonstration field was later planted and suffered badly from cold weather in early summer. If these two farms are removed from the graph, there is a statistically significant response to the extra fertiliser (even taking into account that n reduces to 7). Is this effect due to fertiliser N, P or K?

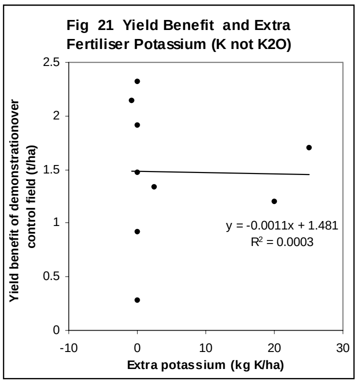
None or very little P and K fertilisers was applied on most fields and certainly on the basis of high levels of soil available P, little response to P fertiliser would be expected (Figures 20 and 21). The origin of the response to fertiliser is seen in Figure 19 to be most likely due to nitrogen, where the range applied varied from little to excessive. The plot of points excluding farms 09 and 18 is shown in Figure 19a where the quadratic response of yield benefit to nitrogen is a better fit than the linear response and statistically very highly significant with P=0.1 percent. About 150kg N/ha extra to the control average of about 100kg N/ha produces maximum yield benefit.









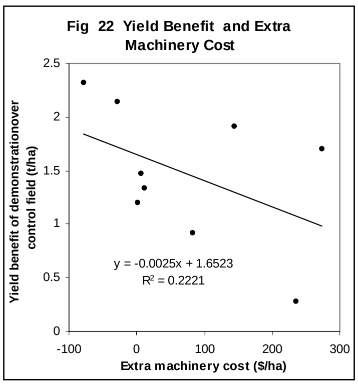


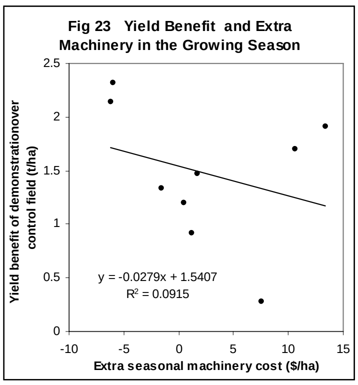
By international standards this is an excessive amount of nitrogen but calculated as kg cotton per kg of N, the result of about 13kg/kg is similar to the average in USA and other developed producing countries. However, the heavy yield on the Bukhara farm (no. 35) shows a return of about 90kg/kg of N suggesting that another factor is affecting the results. It is believed that the keys to improving the productivity of nitrogen are

- Apply small dressings frequently
- Apply the nitrogen by banding close to the plants after, not before irrigation
- Apply nitrogen to the side of the seeds at planting at about 15-20kg N/ha.

3.1.3 Machinery

The extra yield seems to be unaffected by the use of extra machinery during the growing season on the demonstration fields (Figures 22 and 23). Naturally, there is a relationship between extra yield and the machinery required to harvest it.

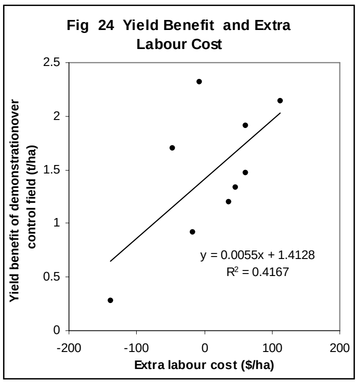


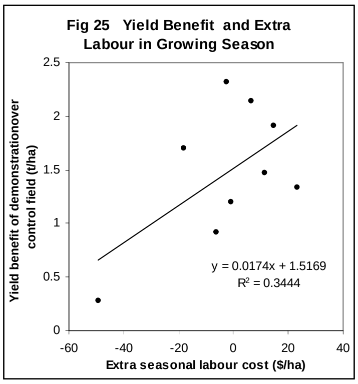


It appears that any extra machinery used in the demonstration fields was wasted investment and that reduction in machinery use is likely to benefit the gross margin by reducing cost more than yield.

3.1.4 Labour

There is some evidence in Figures 24 and 25 that extra labour applied to the crop during the growing season, mainly in control of weeds, may have benefited the crop. The evidence is tenuous, depends on the data from farm 09 and even then fails to reach significance with P = 5 percent.

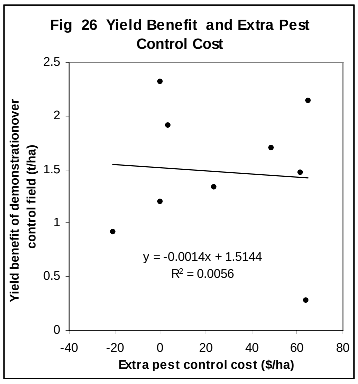


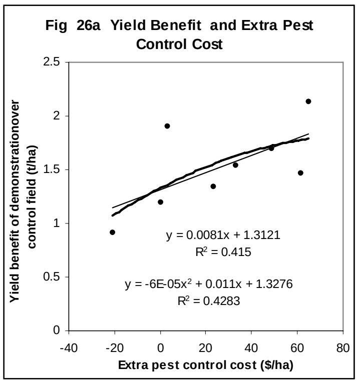


Almost certainly, the key factor with labour is timeliness of operations rather than the total used on the crop. Control of weed competition early in the season to encourage the rapid early growth of the crop before the onset of flowering is vital to obtaining high yield.

3.1.5 Pest Management

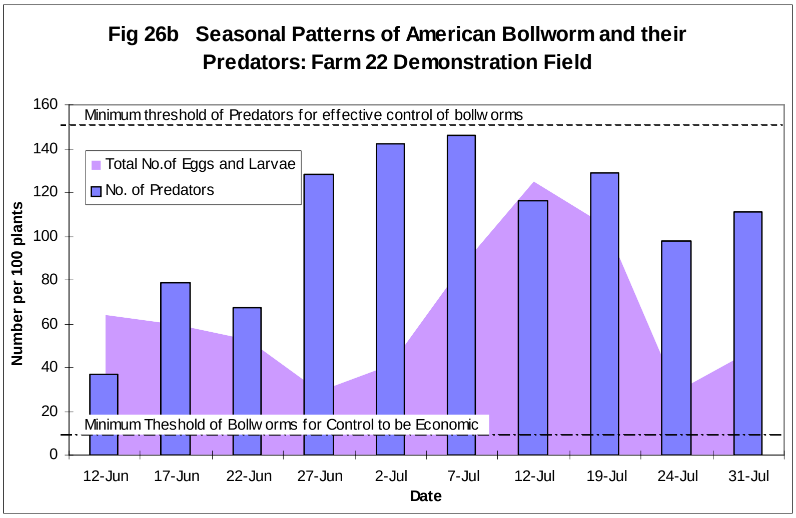
As with fertiliser response, the removal of data from farms 09 and 18 markedly changes the pattern of data as shown in Figures 26 (all farms) and 26a (excl. farms 09 and 18). The fitted quadratic response almost reaches significance at P = 5 percent and seems to show a maximum at about $80 invested in pest control per hectare.





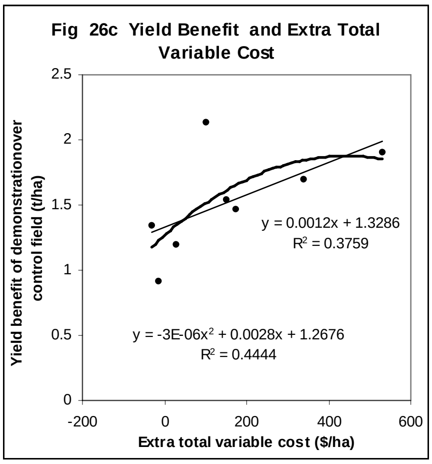
There has not been time in the short time available for writing this report to fully analyse the data available on weed populations and the pest scouting data. Summaries of some of the pest data are given in Annex D.

The RWG hired the services of a specialist entomologist who visited 7 out of the 9 farms and in some cases several times. He was only partially successful in teaching Supervisors, most of whom are hydrologists, how to recognise pests and their predators at all stages of their life cycles. Quality and completeness of data therefore varies between farms. The overall impression is that the four main pests (American bollworm, spider mites, aphids and jassids) often exceeded the threshold level of population at which it becomes economic to control them. Although farm staff took control measures, often too late these were seldom successful. Biological control agents were commonly released on the demonstration field but seldom did the predators reach the minimum population at which they would successfully control the pests. This is illustrated in Figure 26b for Farm 22 in Surkhandariya, where the local hakimiyat had instructed that there should be no use of pesticides in cotton. Throughout the summer the population of American bollworm (*Heliothis armigera*) was far higher than the minimum level for control to be economic and yet the population of predators failed to reach the minimum necessary to control the pests. Considerable crop yield was lost on this farm due to uncontrolled pest damage.



3.1.6 Total Variable Cost

There appears to be no effect of extra total variable cost invested in the demonstration fields and the extra yield produced. However, for the same reason as explained for fertiliser, if data for farms 09 and 18 are excluded, then a statistically significant quadratic response emerges as shown in Figure 26c.



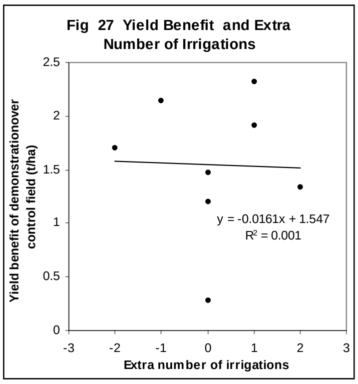
Maximum yield benefit would seem to be produced by a total variable cost investment of about $400/ha.

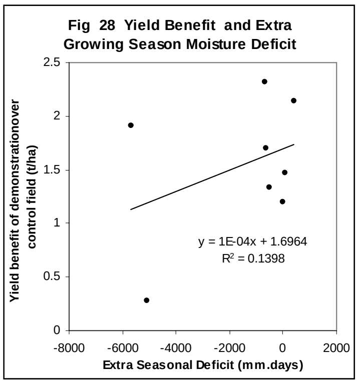
3.1.7 Irrigation Schedules

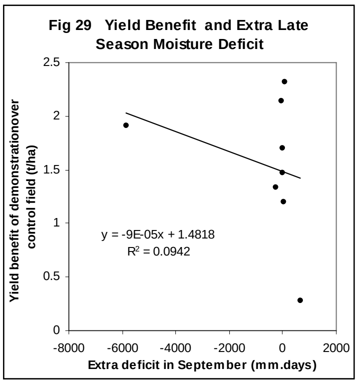
The timing of irrigation normally is a critical determinant of yield. For reasons given above, the considerable contribution by capillarity from the groundwater obscures the impact of irrigation schedules. Figure 27 indicates that there is no evidence that number of irrigations had any impact on the yield benefit of the demonstration fields.

Nonetheless, the detailed schedules presented in Annex F indicate that many crops experienced periods of moisture deficit during the season. The total deficit during the period to 31 August and during September was calculated in mm.days and the difference between control and demonstration fields in these values are plotted against the yield benefits in Figures 28 and 29. Surprisingly, particularly with growing season deficit, there is no evidence of a meaningful relationship.

A number of assumptions could affect the seasonal pattern of soil moisture shown in Figure 10: pan and crop coefficients, depletion factor and the modified Laktaev model to estimate the groundwater contribution. Inaccuracy in measuring the pan evaporation, the crop rooting depth and the available soil water holding capacity equally would distort the pattern. At this stage, it is not possible to say which if any of these possibilities may be responsible for the lack of a mathematical relationship.





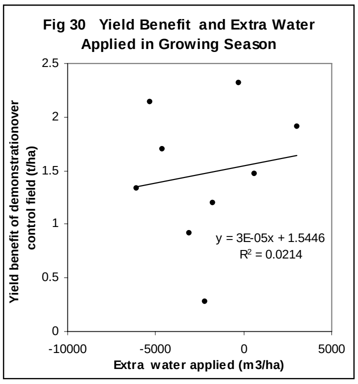


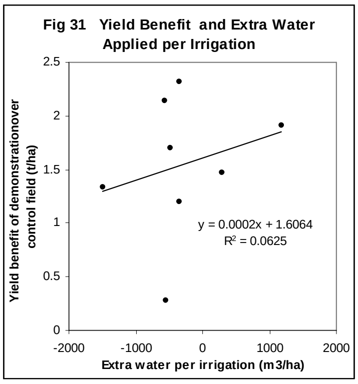
3.2 Water Management

While scheduling indicates the day that the crop should be irrigated and the net irrigation requirement, the science of water management is concerned with applying it as efficiently as possible. Earlier reports devoted to improving water management are reproduced as Annexes B and C.

3.2.1 Gross Water Application

Figure 30 plots the yield response between the demonstration and control fields with the extra water used (+) or saved (-). As expected, there appears to be little relationship since the normal practice in the area is to over-irrigate. However, as shown in the detailed crop budgets (Annex E), there is evidence in several fields of under-irrigation at the peak of summer perhaps due to shortage of water in the supply canal.

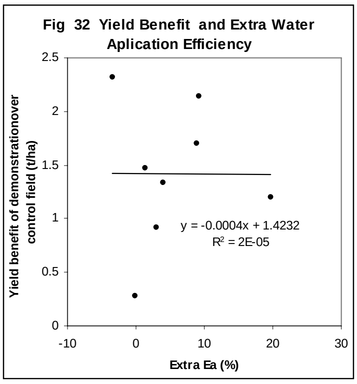




To eliminate any effect of more or less water being used as a consequence of difference in the number of irrigations, Figure 31 shows the relationship between the average gross water application per irrigation and the yield response. Again there is no evidence of any relationship, and with surface irrigation methods there is never likely to be one on account of the very low application efficiencies to be expected.

3.2.2 Application Efficiency

For the reasons given above, there is an arbitrary quality attached to the estimate of overall irrigation application efficiency (E_a). The early irrigations requiring less water to be applied are more difficult to control and application efficiency is expected to be low, with values commonly around 15-25 percent. In mid-season the efficiency rises as the rooting depth increases and with it the net water requirement, when values around 40-50 percent were reached on some farms. With some of the later irrigations, the estimated field efficiency was above 60 percent and in cases, over 100 percent (which is technically impossible) and suspect values were excluded from the overall average for the season. The seasonal average Ea is plotted against yield response in Figure 32, where it can be seen that there is no relationship.



Supervisors were instructed to undertake several furrow flow tests during the season. The methodology is outlined in the Training Manual attached as Annex A. The advantage of such tests is that the distribution of the water applied to a furrow can be accurately assessed between

- recharge of the rootzone moisture deficit (in effect E_a applied to a furrow),
- deep percolation loss below the rootzone and
- escape from the ends of the furrows.

The disadvantage of the method is that the number of tests that can be done is limited and that the choice of location and time may not be representative of the whole field. These tests in themselves take no account of tail escape losses from the field canals as do the estimate of overall E_a discussed above.

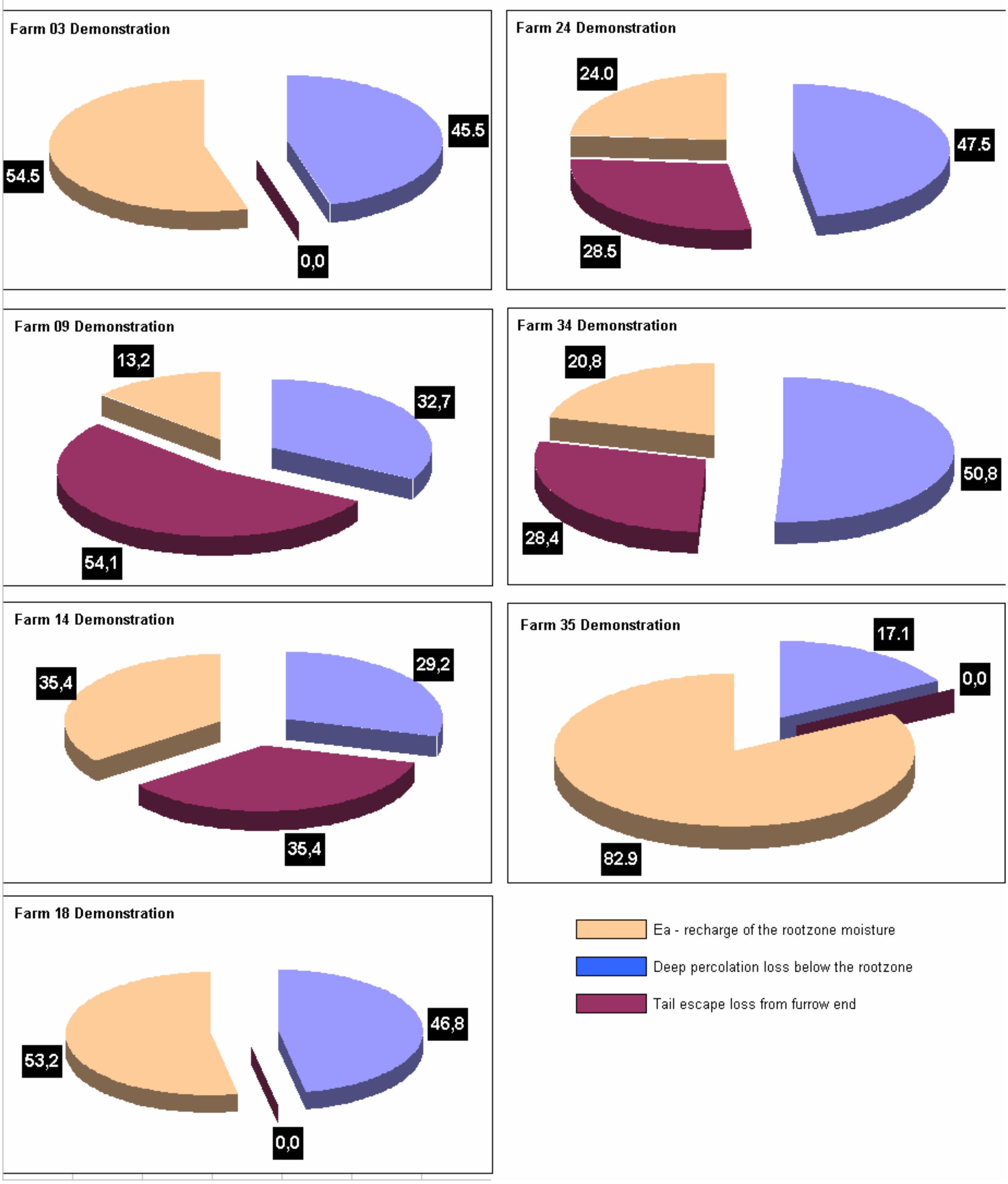
Weighted average values of the distribution of the water delivered to the test furrows are illustrated in Figure 33 for several demonstration fields. There is considerable variation in the E_a component from 13 percent in Farm 09 on a steep slope, to 83 percent in farm 35.

In the prescriptions for water management issued at the training seminar (Annex A) and in the review report of July (Annex B) attention was drawn to the difficulty of irrigating the demonstration fields on Farm 09 and Farm 22. The water management program PUMA predicted serious erosion of soil down the furrow on Farm 09 and this is clearly visible in the Photograph Section. It was recommended that reeds cut from surrounding drains should be laid in furrows of Farm 22 to slow down the water flow but this was not done and higher than average water use was recorded. The very high value of E_a recorded in furrows of field of Farm 35 is much greater than predicted in the earlier prescriptions, due probably to the use of short, blocked furrows on this level field. PUMA currently is available only with the model for open furrows with tail escape.

Some farms (nos. 03, 18 and 35) practice the blocked furrow method of irrigation so that there was no runoff in these cases. This is particularly appropriate in level fields, as on Farms 18 and 35. The size of the tail escape component largely reflects the slope of the furrows, decreasing in the order farm 09>farm14>farm24>farm34. The tail escape from short, steep furrows generally is not a hydraulic loss since it augments flow in the temporary field canal below.

Deep percolation loss is both an economic and hydraulic loss (except where groundwater is reused for irrigation, albeit somewhat salinised). Deep percolation losses ranged from 17 percent in Farm 35 to 51 percent in Farm 34, from the acceptable to the unacceptable.

Fig 33 Breakdown of Water Distribution from Full-Furrow Tests - (weighted average percent)



3.2.3 Slope and Length of Furrows

The topographic survey of fields at the start of the season was reviewed in the July report in Annex B. It was concluded that design lengths of furrows were much too long and needed to be subdivided by temporary field canals if significant improvement in application efficiency is to be achieved. The second reason for subdividing furrows was seen to be the unevenness of the fields, in some cases, slope reversing at different points along the furrow. This is a major issue and will only be solved in the long-term by considerable capital investment in land levelling.

It seems likely that the original levelling at the time of land development was often poorly executed. Since then, the situation has been aggravated by poor land preparation. Reversible ploughs were not offered in the list of Soviet machinery and by tradition it has been necessary to plough in blocks, leaving opening furrows and closing ridges across the field. Heavy use of secondary tillage equipment traditionally tended to smooth these out before planting. Recent imports of American tractors with 5-body reversible mouldboard ploughs have provided the opportunity for good land preparation. It seems that drivers have been instructed to “save on the cost of replacement plough components” by not reversing the ploughs at headlands but rather to plough in blocks in the traditional manner. Drivers may also be saving on fuel by ploughing shallowly at high speed so that as the topsoil settles after spring rain, ridges appear equivalent in width to the plough width (see Photograph Section). The adequate relevelling of these ridges by secondary tillage would be unnecessarily expensive, and scarcity of machinery now makes it unlikely.

3.2.4 Furrow Profile and Roughness

The Manning equation of hydraulic flow along furrows is the basis of the water management program PUMA. It is sensitive to assumptions about furrow section and roughness. The short review report of September (Annex C) concluded that the earlier assumptions of furrow shape parameters were incorrect. Values calculated for each farm were not dissimilar perhaps on account of the use of the same machinery for interrow cultivation work. Were ridgers to replace interrow cultivators for this operation, then the shape parameters would be expected to be different. The other conclusion was that there is a marked difference in parameters before and after irrigation as the profile slumps. This requires that accurate estimates of the parameters should be made both before and after irrigation.

At the time of writing, there has not been time enough to use the PUMA program to systematically change the Manning roughness coefficients, together with the revised shape parameters, in order to reconcile the furrow flow tests with the model output. It is an important exercise if PUMA is to become a useful tool for prescribing water management criteria.

3.2.5 Duration of Irrigation and Furrow Flow Rate

Now that it is revealed that three out of the farms used blocked furrows, the PUMA model needs to be developed to accommodate this situation.

The conclusion from the July report (Annex B) is that furrow flow rates by tradition are too low and need to be raised, while durations are shortened in order to raise the E_a of irrigation. It is clear that most Supervisors failed to accommodate to the prescriptions and consequently, the improvement in application efficiency was not as great as it could have been. There is inertia to change purely out of tradition, but as concluded in the earlier report, the changes conflict with the “convenience factor” that allows the irrigators to leave the fields during irrigation to undertake other, and mostly personal business. If improvements are to be achieved, all people involved in the irrigation industry must adopt a new “mind-set”.

3.2.6 Planting under Plastic Film

The area of cotton planted under plastic film was less in 1999 than earlier but was still a large area particularly in the Ferghana Valley. It is claimed that the film protects emerging seedlings that may be planted two weeks earlier, reduces evaporation from the soil surface and discourages weed competition. Extra yield of about 680kg/ha of raw cotton at financial and 330kg/ha at economic prices is required to cover the cost of about $150/ha.

A special planter has a roll of 0.6m wide polythene mounted over each row that unrolls as the tractor moves forward, a share covering the edges with soil. Mounted behind each roll is a large, hollow land wheel filled with seed, and hollow conical “spikes” around the perimeter that penetrate the plastic at about 10cm intervals depositing several seeds by gravity at about 5cm depth. Considerable extra labour is required to refill the large planting holes with soil, often mixed with composted manure. It is impossible to band fertiliser near the seed at planting so P fertiliser needs to be earlier broadcast and ploughed, leading to considerable fixation of expensive P by the soil. The vital early N for germination is missing (apart from the small amount in the manure) and plants only receive any when lateral roots are long enough to intercept side-dressed fertiliser N outside the plastic. Germinating weed seeds penetrate through the hole in the plastic together with the germinating cotton seedlings and are difficult to disentangle aggravating early weed competition. Late frost in 1999 killed seedlings over a wide area planted early under plastic that required manual replanting.

Demonstration fields on farms 09 (Kyrgizstan) and 34 (Ferghana) were planted with this system but there is no evidence that it improved water productivity by increasing yield, increasing gross margin or saving water.