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REVIEWS

DIRECTIONS FOR SEMICONDUCTOR WAFER-FABRICATION FOR TWENTY FIRST CENTURY

A.J. Hamdani*

ABSTRACT

Research work carried out in the last decade on the Microelectronics Manufacturing Science and Technology (MMST) program sought to address a need for increased flexibility in IC manufacturing through single-wafer processing, with in-situ sensors and real-time process/factory control has lead to a successful demonstration of a novel approach to IC manufacturing based on flexible process.

To make it possible for modern industry to utilize MMST program, one can make use of programmable process-tool with technology of computer-aided design (T-CAD) and Process Synthesis.

Computer-Integrated Manufacturing (CIM) links equipment, people, and products in a manufacturing facility. Today's manufacturing requires "agility" - the ability to thrive in a continuously changing, unpredictable environment [1], which can be achieved by using advanced monolithic CIM systems.

This article presents an overview of strategies employed in the MMST program to build a flexible, distributed, CIM system-framework, with applications that exploit new hardware, process-technologies, and Process-Synthesis for agile and cost-effective wafer fabrication.

PROCESS-SYNTHESIS FRAMEWORK (PSF)

The Microelectronics Science and Technology (MMST) approach has successfully demonstrated a novel approach to IC manufacturing, based on flexible process equipment [2]. The next step is to make it possible for modern industry to make use of these developments, applying "Process Synthesis", making use of programmable process-tools with technology of computer-aided designs (T-CAD) and process-models, within a framework called "Process Synthesis".

This will allow designers to prepare a manufacturing process-flow and to produce an IC in which performance, reliability, manufacturability, life-cycle cost, and cycle-ti me have been optimized.

The architecture is shown in Figure-1, as envisaged for semiconductor manufacturing facility of the future.

The most important part is the tight integration of a virtual (simulated) factory and a programmable production-facility. The actual production-line would follow the MMST model, with flexible, microprocessor-equipped process-tools, linked to a host-computer-integrated manufacturing (CIM) computer, which would generate an optimized use of equipment for each device.

The first step is to create a PSF, so as to simulate and optimize a virtual product from a design. A PSF might include the following:

- Integrated process and equipment models for each tool;
- Unit process-specification and product-description data-base;
- Product simulation;
- Manufacturing rule checker;
- Process sequence optimizer.

The output of the PSF would then be passed on to the MMST production-line for execution. T-CAD tools, which provide a model of the unit-process steps and process-integration, need to be integrated with the programmable factory. Companies will therefore use these T-CAD models to develop standard and reusable process-libraries, which will provide the fundamental "building blocks" of a manufacturing-sequence. Once these technologies are developed, the integration of manufacturing-process and circuit-design can begin.

PROCESS SYNTHESIS—ITS DESIGN AND WORK

A central data-base of unit process specifications would provide general parameters for a given process;

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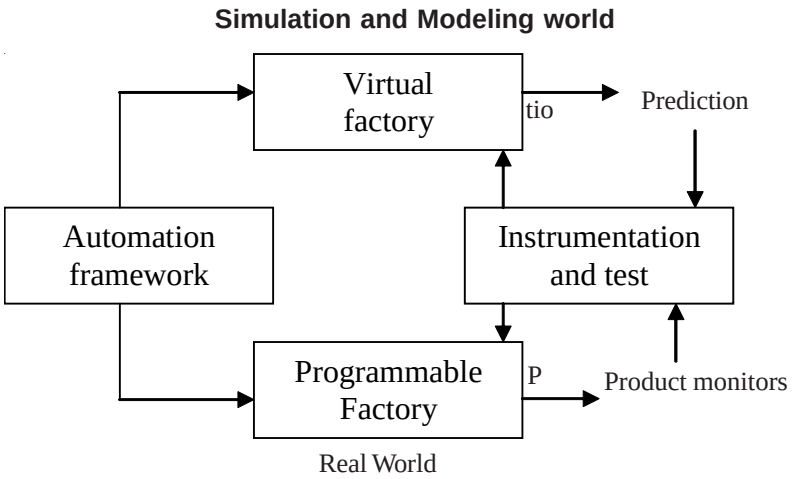

Figure - 1: Semiconductor manufacturing in the 21st century, with a Process Synthesis framework

these parameters would be obtained from a complete product-simulation in the PSF. Rule-checker would check the product-simulation against the process-capability of each tool, taking process-interaction into account. The database of the checker would be automatically updated when tools with improved processing-capability are inserted into the line.

Other software components would include a process-sequence optimizer, to ensure maximum utilization of equipment and a product-description database to evaluate each product for performance, reliability, and cost. This integrated tool-set would be able to simulate the complete design, evaluation, and manufacturing-process before starting with silicon.

An example of a PSF is shown in Fig.2 Assume that a design-framework has been used to define the architecture, circuit-implementation technologies, and some physical characteristics of an IC. This information forms the virtual product-description, linked to a device-engineering framework for checking. Here, consistency with design-rules is checked; performance, reliability, etc., could be estimated. Design-data passed on by the device engineering-framework is used by PSF for an initial attempt at process-development. A process-sequence is then determined, simulated, and optimized. Depending on the results, a new virtual product could be defined and fed into the device-engineering framework for further refinement or simulation.

The process would continue until an acceptable product-design and manufacturing-process are generated and passed on to the factory for production, as shown in Fig.2.

MMST PROGRAM

In the fourth decade of the IC business, manufacturers are looking for new ways to add value through product-differentiation. Comparison of MMST vs conventional processing is shown in table 1 below.Two possible differentiators are custom-processing and very short delivery-time for new application-specific IC designs. But fast turn-around for new designs is difficult to achieve with today's high-volume wafer-fabs. Another problem is the huge minimum investment

The MMST program is a solution for increased flexibility in IC manufacturing, through research on single-wafer processing with in-situ sensors and real-time process/factory control. Advanced CIM, including real-time process-control, should also help the semiconductor industry.

Modular Single-Wafer Equipment:

MMST's impact on the cost elements is mainly due to a transition from unique, standalone batch-tools to modular single-wafer plasma, vapor-phase, or boatless wet-process, and rapid thermal processing (RTP).

The MMST vision for equipment includes the greatest practical degree of modularity (see fig 3). Ideally, most

Table - 1: MMST vs. conventional processing

Current technology	MMST technology
Large, fixed, 20,000-Wafer capacity	Modular, 100- to 1000-wafer/month capacity
Factory costs>$500M	Factory costs $30M-$50M
Silicon only	Generic manufacturing (HgCdTe, GaAs, etc.)
Class 1 cleanroom	Class 1000 cleanroom
30% of processes use liquids	Liquid-free processing
25- to 50-wafer batches	Single-wafer processing
Batch sampling	Real-time process control
Long cycle time, 1-3 months	Short cycle-time, 5-15 days
Mixed equipment-configurations	Modular vacuum-processing equipment

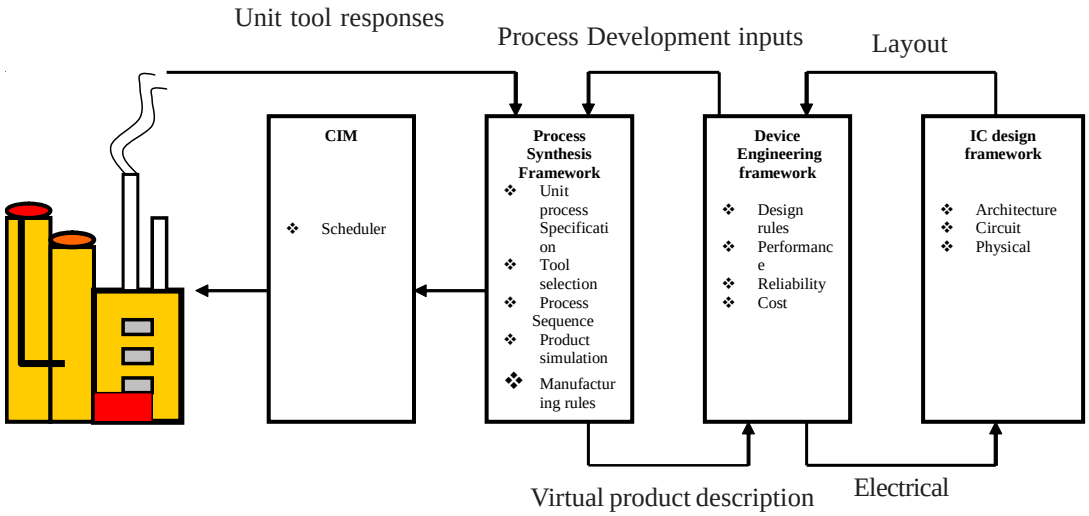

Figure - 2: Design and process synthesis integration

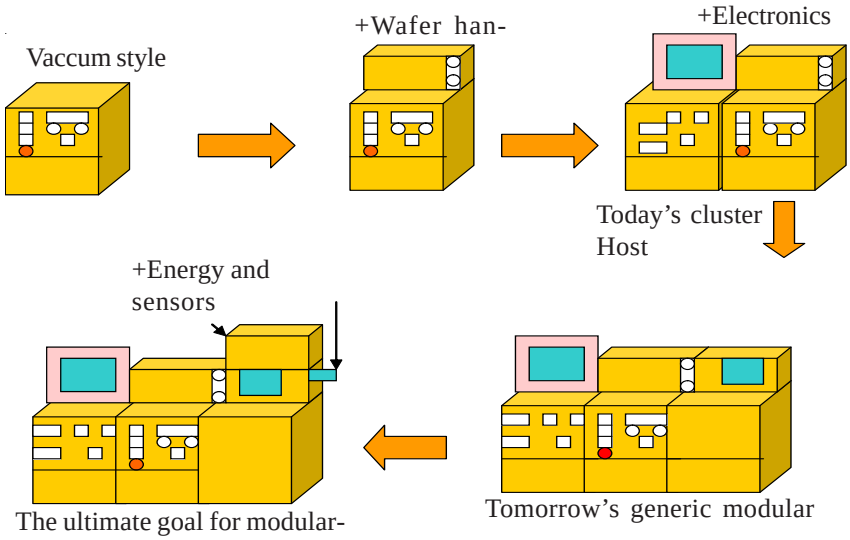

Figure - 3: Process-tool equipment should be standardized around basic subsystems to achieve a high degree of modularity for flexible manufacturing.

tools would look almost identical physically and would be distinguished only by the specific energy-sources and sensors that were attached to the process-chamber. All wafer-handling, gas-distribution, vacuum, computer, etc, subsystems, as well as the process chambers would be identical.

Figure 4 shows the results of a factory-level analysis of relative wafer cost vs cycle time. It is apparent that the single-wafer fade exhibits less sensitivity of cost over a wider range of cycle times. Another alternative way is to employ an appropriate CIM system for such analysis. For example, a commercial CIM software system evolved from the MMST programs that it should be able to predict fab cost/performance changes associated with adding or changing a particular piece of equipment without having to input a complete fab description into a stand-alone Factory-simulation program.

Computer-Integrated Manufacturing (CIM)

Requirements of a CIM system for agile semiconductor fabrication in the MMST program [2] were derived, analyzing the objectives of the manufactory.

Capabilities, cost, and other characteristics of current IC manufacturing technology versus those for flexible, low-volume MMST technology are compared in table 1. As shown, typical factory cost based on MMST technology range from $30-50 million, whereas traditional large-volume wafer-fab facility now costs atleast $500 million, and some even $ 1 billion or more. Furthermore, a low-volume MMST-like facility allows cycle times less than two weeks for new devices, compared to about three months in large-volume factory.

CIM offers great hope for dealing with the future IC production, by providing the flexibility, full integration, functionality, cost-effectiveness, maintainability, and ease of use that would encourage widespread adoption by IC industry.

Object-Oriented CIM System Architecture

Architecture of a distributed object-oriented CIM system is multidimensional. Two important dimensions, the logical and the physical, are shown in fig .5 .The physical architecture is shown on the right side of fig .5. Objects are grouped by many “using” or “containing” relationships and distributed to the various computing-nodes throughout the factory. For example, a machine (object) contains many other objects (e.g.; chambers, valves, robots, pumps etc). These are instantiated on the various computers within specific machines, such as the host user-interface computer and one or more process-control computers.

The logical architecture is represented by the object class-inheritance hierarchy. At the top of the hierarchy stand the most abstract and generic classes (e.g., Document, Plan, Resource, and Material). At the bottom of the class hierarchy lie the most concrete and specialized classes [e.g.Process Spec, Wafer Start Plan, Advanced Vacuum Process (AVP), and wafer].
The services provided by CIM system are portioned into eight major applications-Factory Manager, Factory Planner, Factory Scheduler, Factory Simulator, Specification Manager, Generic Equipment Model (GEM Software), Machine Control, and Process Control.

The highest-level application in the CIM system, the Factory Manager, contains many factory-level abstractions (e.g.Factory, Area, Material, User, Material Transporter) that tie all the applications together. The Factory-Manager application provides services for starting up and shutting down the factory and for coordinating the activities of operation-management personnel while the factory is running. Fab-performance monitoring (e.g.throughput, cycle time) and work in progress (WIP) tracking facilities are provided.

The Factory Planner is the focal point for accepting factory-orders and generating a production-plan that pinpoints which wafers are to be processed by the fab during each time-period. This model works hand-in-hand with the Factory Scheduler, with the scheduler being responsible for driving the factory to meet delivery-schedules, specified by the Planner. Collaboration between the Planner and the Scheduler controls material-release into the factory; the Scheduler controls when the material is released and the Planner controls what material is released. The Planner, also, continuously take care of any changes to the plans or resources, and the output can be used

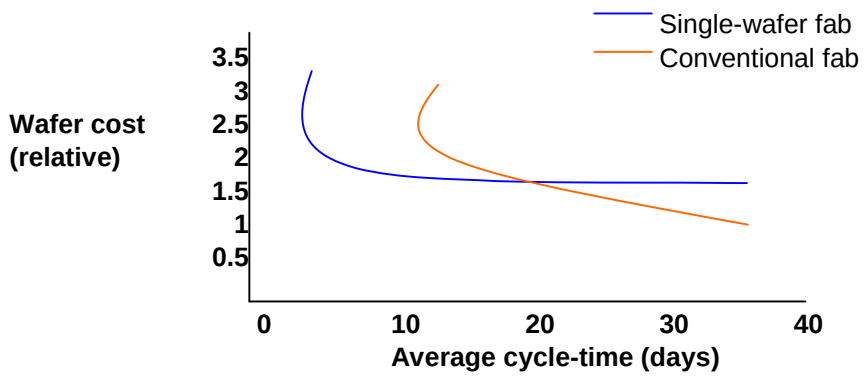

Figure - 4: An example of cost vs. cycle-time for wafer fabrication. Total single-wafer processing offers shorter cycle-times than today's mix of both batch and single-wafer Processing. There is also less variation in wafer-costs over a wider range of cycle-time

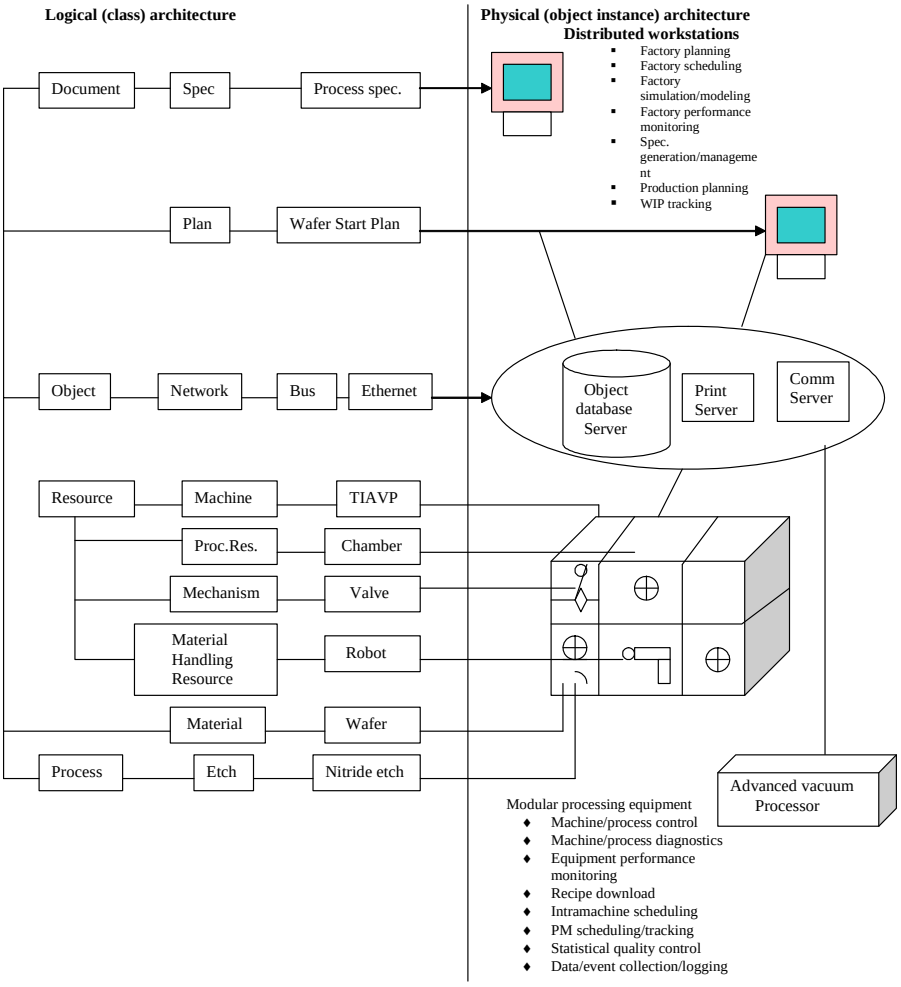

Figure - 5: System-architecture for the object-oriented CIM software. Architecture can be visualized in the logical domain (left) or physical domain (right)

with the Factory Simulator to verify the plan via simulated production.

Scheduling of production-operations is controlled by the Factory Scheduler. The Scheduler decides when material is to be processed by each machine and directs the factory-resources (people and machines) to effect those decisions. Scheduling-decisions are based upon the production strategy, the real-time factory status, machine-performance history, while machine failures and preventive maintenance (PM) actions are accommodated.

Mechanisms required to conduct discrete-event simulations of factory-operations are provided by the Factory Simulator. The Simulations are controlled by user-defined experiments, specifying the factory-configuration and any starting and terminating condition. A computer-aided process-engineering environment is provided by the Specification Manager, to generate and manage various CIM system-specifications. The Specification Manager includes editors (for entering and modifying new process-steps, sequences, and flows) and an engineering change notice management-system.

GEM includes all aspects of common machine-operation, including material-transfer, intramachine scheduling, material-processing, data-collection, performance-monitoring, and preventive maintenance (PM).

Machine Control is responsible for controlling sequencing and settings of the various machine-resources, in response to external commands for processing. Any specialization of GEM required for a specific type of machine is also provided by Machine Control. This can include specialized sensors, calibration procedures, maintenance-instructions, and programs for controlling unique machine operations.

Ensuring consistency and quality of processing for a specified machine is the responsibility of Process Control. This requires translation of the desired effects, as specified by the machine-independent process-specifications, into actual machine settings.

CONCLUSION

Intelligent and flexible process equipment *of the future* could enable a process synthesis framework for simulating and optimizing virtual products from design. There is a need for agile manufacturing calls for more-flexible CIM systems, allowing economic production of smaller lots and the ability to adapt to advances in hardware and process-technology. This Object-oriented CIM software for the Microelectronics Manufacturing Science and Technology (MMST) program is required. It is also important to explore the extension of present models to flexible, shorter cycle-time manufacturing, using modular, single-wafer processing tools, such as those developed for the MMST project.

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METHODS OF ABSOLUTE LASER MEASUREMENTS OF GRAVITY-CONSTANT "g"

*M.M.S. Gualini**

ABSTRACT

We propose a modified Michelson's interferometer, with some applications in dimensional metrology. The configuration of a Michelsons' interferometer, using corner cubes instead of plane mirrors, is further modified in a rectangular parallelogram. A double prism is introduced in one of the branches of the device, in order to obtain a precision of $\lambda/4$ and an accuracy of $\pm\lambda/8$. The same scheme can be applied to develop absolute portable gravimeters. We present an interferometer-version, enabling us to reduce the free-fall dropping height to less than 25 cm, which is that size of any available device of the same class. Another version of the same interferometer enables a theoretical doubling of the dropping-rate and a reduced dropping-length, with an effective improvement of the measurement-precision of g. This solution may lead to a portable absolute dynamic gravimeter. The paper discusses the mathematical model, in terms of transfer-function of "g", and describes the modified Michelson's interferometer with a 'futuristic' solution for a dynamic portable absolute gravimeter.

Keywords: thickness, refraction index, gravity constant "g", laser absolute portable gravimeter, Michelson's interferometer.

INTRODUCTION

We had proposed the use of a modified Michelson's Interferometer for fast and accurate alignment of U-fold high-power gas laser cavities[1], hinting at a possible further modification. Theoretical work in the latter modification has enabled consideration of some applications in metrology. Infact, the modified Michelson's Interferometer (MMI) presented here can be used to measure rotations with small angles and thickness of transparent components like "optical flats", with $\pm\lambda/8$ accuracy. It can be used also to test and measure the backlash and motion-linearity of translation stages. But we found a quite interesting application to develop a new absolute laser gravimeter, with improved precision, accuracy and reduced dimensions. Studies[2÷7] on previous portable laser gravimeters have shown that reduction of the free-fall height[8] and rise and fall[9] configurations may lead to the design of portable laser gravimeters of improved performances and, above all, enable us to realize also portable absolute dynamic laser gravimeters.

2. GENERAL AND THEORETICAL DISCUSSION

2.1 The two versions of the modified Michelson's interferometer

The two versions of the modified Michelson's interferometer are shown in figures 1 and 2. We will concentrate the discussion on the version with a double prism DPMMI (Double Prism Modified Michelson's Interferometer), owing to its advantages, including a $\lambda/4$ precision and $\pm\lambda/8$ accuracy. Figure 1 shows the original scheme proposed for accurate fast alignment of U-fold laser cavities[1]. From this simple design, we derived the DPMMI of figure 2.

A Double Prism is introduced in the scheme of figure 1 and is fixed in its position, once properly aligned. Thus, typical Michelson's fringes can be observed when the displacement, Δp (M_1 and M_2, part of the same prism, move simultaneously), is equivalent to:

$$\Delta p = (1/2)\cdot(M_p + ½)\lambda_0 = (2M_p + 1)\,\lambda_0/4 @\ Mp = 0, 1, 2, \ldots (1)$$

where λ_0 is the stabilized wavelength of the laser source. Beside the advantages of improved precision and accuracy, the insertion of the double prism enables a direct control of the misalignments. Infact, a double spot detected by the receiver, a CCD camera, instead of the fringes, will be the direct information that the interferometer has lost its alignment. This information can be quantified after proper calibration and the distance between the two spots on the CCD will be proportional to the misalignments. The relative displacement of the two beams on the CCD surface will also enable us to determine the orientation of the misalignments, so that error-compensation can be carried out automatically.

Beside the development of a quite compact, absolute laser gravimeter, the DPMMI has some other

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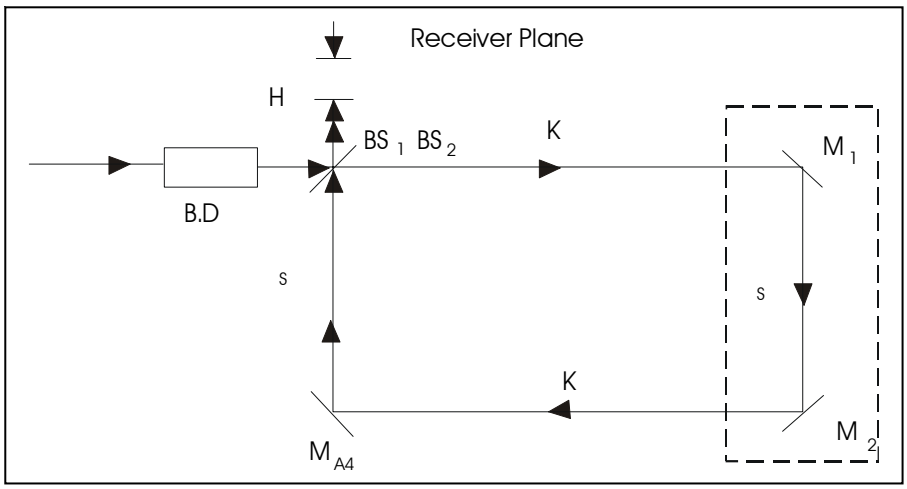

Figure - 1: First version of the modified Michelson’s interferometer[1].

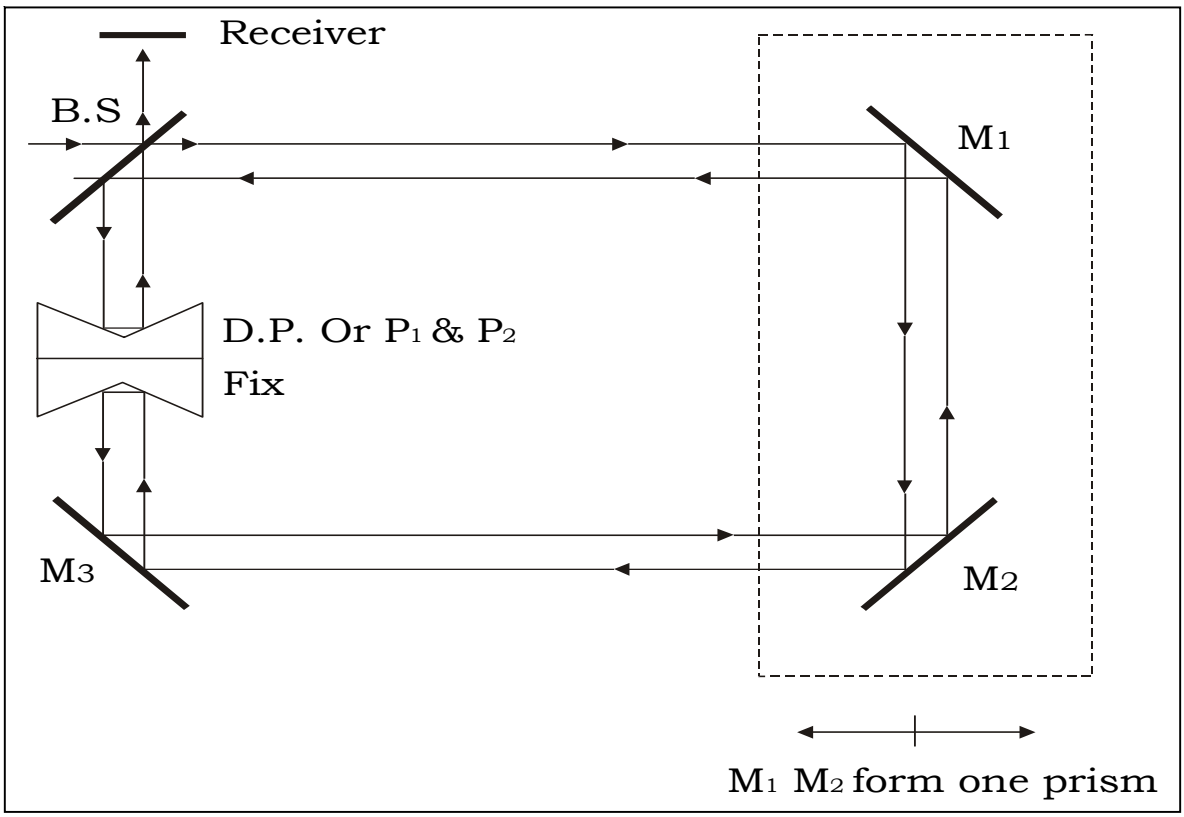

Figure - 2: Final version of the modified Michelson’s interferometer[1].

applications in Metrology, which are briefly discussed in the following section.

2.2 Some applications in Metrology

With reference to figure 2, the DPMMI can be used to test and characterize translation-stages, once M_1 and M_2, part of the same prism, are installed on the moving part of a precision sliding ruler, or a translation stage. Positional accuracy and repeatability can be monitored and measured directly; eventual backlash and tilts can be indicated by the missed overlapping of the two interfering beams, as already discussed above.

The DPMMI can also be used for precision measurement of small rotary angles, or the measurement of the thickness or refractive index of transparent flat components, as is visible in figure 3. The transparent object of thickness t and refractive index n_β will introduce a beam path-difference Δp, so that the number of fringes M_p may be counted. From figure 3 it can be easily derived that $\Delta p = t/\cos\beta$, which can be compared with the measured $\Delta p = (2M_p+1)\lambda_0/4$ @ (M_p= integer), so that we can write the identity expressed by equation (2):

$t/\cos\beta = (2M_p + 1)\,\lambda_0/4$ @ M_p= integer reat out from counter (2)

Equation (2) can be used to determine, alternatively, thickness or refraction index of the transparent object under test, when the other variable is known. Assuming that n_α, the refraction index in vacuum, is equal to 1, the Snell's law, $n_\alpha/n_\beta = \sin a/\sin b$, becomes $n_\beta = 1/\sin\beta$, since α=90°. A method to measure contemporarily the thickness of the transparent object and its refractive index, taking advantage of the interferometer accuracy. This is possible when we install the transparent object on a rotary stage and take two measurements, one with α=90° and the other with α=85° that corresponds to a rotation of the transparent object by δ=5°, for example. By the square triangle property and the Snell's law, we can write a set of two equations with two variables, t and β, as follows:

$t/\cos\beta = (2M_1 + 1)\,\lambda_0/4 \equiv a$, @ M_1= integer from counter read out (3)

$t/[\cos(90° - \delta - \beta)] = (2M_2 + 1)\,\lambda_0/4 \equiv b$, @ M_2= integer from counter read out (4)

where "a" and "b" are known from the measurement of the fringes, $(2M_1 + 1)\,\lambda_0/4$ º a and $(2M_2 + 1)\,\lambda_0/4 \equiv b$, respectively. Assuming δ=5° and developing cos(90° - δ - β) º cos(85° - β) in (cos85°sinβ + cosβsin85°)= k_1 sinβ + k_2 cosβ, where k_1 = 0.087155… and k_2 = 0.996194…After obvious passages, the solutions of the two variables set of equations (3) and (4) is represented by:

$\beta = \arctan[(1/k_1)(b/a - k_2)]$; $t = b\cdot\cos\beta$; $n_\beta = 1/\sin\beta$ (5)

PC software may solve automatically for the values expressed by equations (5), once data (M_1, M_2, δ) are properly entered.

3. THE PROPOSED PORTABLE ABSOLUTE LASER GRAVIMETER

There are many types of gravimeters, each of them based on a different physical principle. Main distinction is between absolute and relative gravimeters. The first type calculate gravity from data directly measured with primary standard instruments, while the latter rely on indirect relations with primary standards. Majority of portable gravimeters adopt the so-called "free falling" method. An optical prism, the mass, is dropped inside the chamber, defined as "dropping-chamber". The descent of the free-falling object is monitored very accurately, using a Michelson interferometer with prismatic mirrors. Therefore, the measure of the free-falling path is reduced to a fringe-count, using an electronic digital counter. The total fringe count, N, is then multiplied by the interferometer fringe order, $\lambda_{HeNe}/2$ in the case of HeNe laser source in a Michelson type, so that $H \equiv N\times\lambda_{HeNe}/2$. The free-falling time is measured by an atomic clock, generally a portable rubidium device. The HeNe laser emission-frequency is locked on a stable and repeatable atomic transition. Laboratory-made devices of this type have long-term stability better than $\Delta\lambda/\lambda_0 = 10^{-9}$, λ_0 being the locking wavelength. Since the definition of the meter, as absolute length-standard, is a multiple of this l_0, therefore the value $H \equiv N\cdot\lambda_{HeNe}/2$ represents an absolute measure. An atomic rubidium clock registers the free-fall time between two reference points, thus allowing an absolute time measure. Consequently the value of g calculated in the case of the free-fall gravimeter[2] and obtained from the following equation is an absolute value:

$g = 8\cdot H/(T_1^2 - T_h^2)$ (6)

Where H is the free-fall length, T_1 and T_h are the start and stop times, respectively, corresponding to the same free-fall length. General scheme of this gravimeter is shown in figure 4, from reference 6. A motor drives a cart that falls with the corner-cube - prism. The laser beam back-reflected by the reference corner cube prism combines with the beam back-reflected from the free-falling corner-cube-prism on the surface of the photo detector, generating classic Michelson fringe patterns. An oscilloscope monitors and records the interference fringes, while, in parallel, a counter counts them. Reference photo-detectors automatically start and stop fringes-count and time-measure.

In order to appreciate the improvements of the proposed solution with respect to the current available portable absolute gravimeters, we briefly recall here below the state-of-the-art of this class of instruments.

3.1 First generation free-fall absolute gravimeters

Drawbacks of the first-generation free-fall absolute gravimeters are their size and weight. Despite the claimed portability, the devices were quite heavy and cumbersome, requiring separate vacuum-pump and a rack holding all the basic instruments and the service electronics. Also, the laser would have been installed separately, eventually complicating alignment procedures. For example, the first prototype of the device described in reference[2] was almost 1.5 m tall and ~300 kg total weight. The commercially available FG5-L[8] has a weight of 57 kg and is 0.75 m tall. But the absolute gravimeter recently introduced and described in reference[4] is basically one fifth of the size of the FG5-L, which makes it a possible candidate for absolute dynamic measurements. Reduction in size of lasers, PC's, electronic boards and vacuum pumps will be the determinant to further reduce the size of future devices of the same type.

Easy transportability is not the only reason behind the continuous trend to reduce the size of absolute gravimeters. In fact, as pointed out by Marson and Faller[9], the slow acquisition-time was assumed as being the main limitation of the R&F free-fall absolute gravimeters. Quite obviously, longer is the ballistic trajectory, H, the longer is the total time of measurement, including the time to invert the path, as is quite evident from figure 5, showing the characteristic transfer-function of a rise-and-fall device[2]. Shorter acquisition-time means higher precision. For example, the latest device described in reference[4] has a throw-rate of 100 cycles/minute and a best-case single-throw precision of ± 4.0 μGal (1 Gal = 1 Galileo = 1 cm/sec^2 - in these units g = 980 Gal). The precision of the early prototype of reference 2 was ± 20.0 μGal and its throw-rate in the range of 2 –5 per minute, which was preventing a full field operation, due to the effects of perturbations like wind and temperature changes. The total free-fall time per minute of observation has increased almost one order of magnitude, compared to other previous devices[4].

Therefore, size-reduction is extremely important to improve the performances of absolute free-fall gravimeters, leading towards full field dynamic absolute, g, and measurements. Figure 6 shows the surface graphic of the total height, $H = 1.22625\,(T_I^2 - T_H^2)$, in case of R&F-systems. Figure 6 shows that, in order to have measurement periods of 200 ms, the chamber height has to be approximately 50 cm. Similarly, for the single drop in free-fall, the authors of reference 4 report a limit of 20 cm for the drop height, for the same measurement period. Obviously it is a matter of trade-off between period of measurement and height of drop. It is worth noticing that an height of 35 cm is reasonably comparable to a portable dynamic gravimeter, but in the case of spring-type meters, the typical filter duration is 120 s or more, while free-fall devices show measurement-periods shorter than 200 ms.

The advantage of short drop-heights is double, gain in the form of size-reduction and increasing the measurement-time or duty cycle[9]. In fact, the repetition-rate directly influences the measurement-precision, this precision is usually given in μGal/√Hz. From equation (6), figure 4 and 5, it is quite evident that the shorter the stop time, T_H, the higher will be the repetition-rate and, consequently the precision in μGal/√Hz. A value reported from reference[4] is of 3 μGal/√Hz.

3.2 The Drop method versus Rise and Fall (R&F)

Practical realization of an absolute gravimeter is not a simple task, especially from a mechanical point of view. Beside the necessary design that may grant

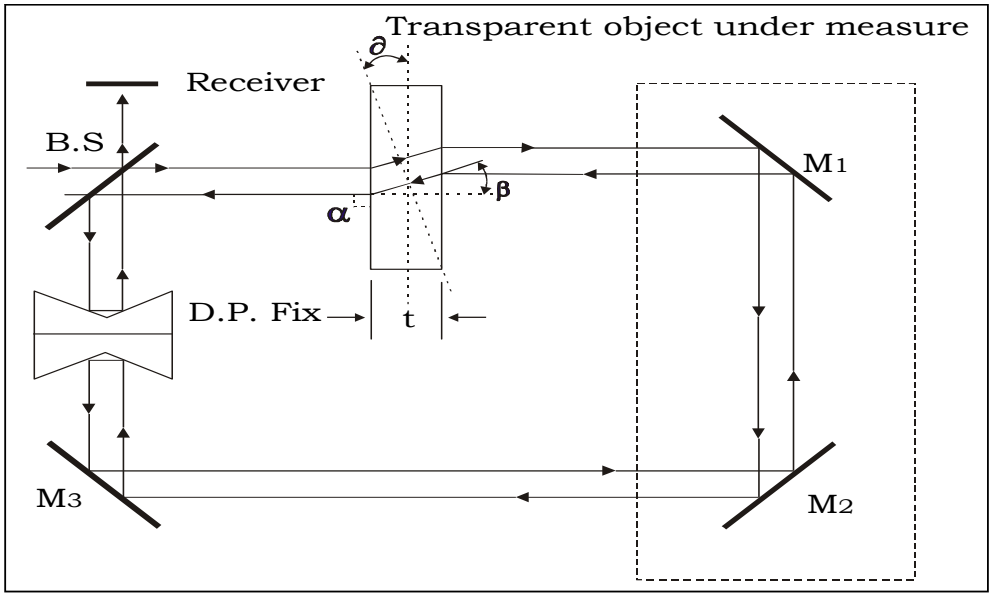

Figure 3: DPMMI setup to measure thickness and refraction index of transparent objects.

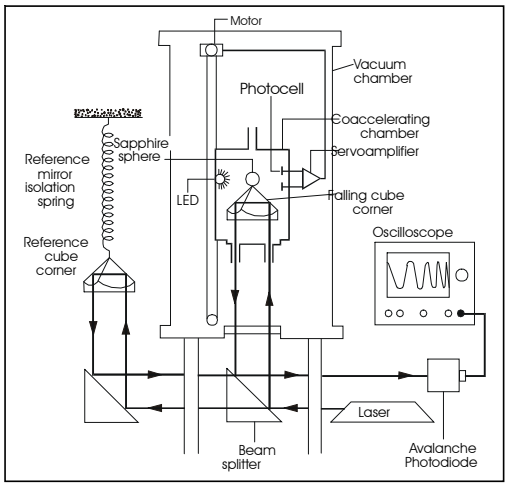

Figure 4: Diagram of the free-fall apparatus from reference[6].

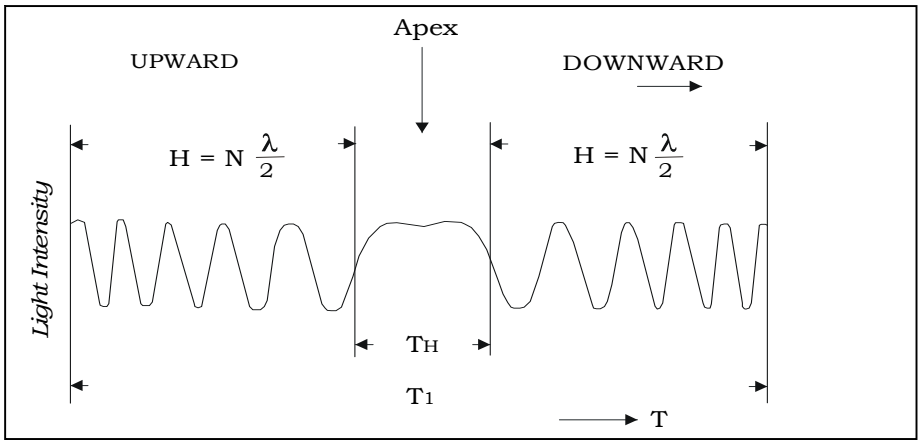

Figure 5: Characteristic transfer function of a R&F absolute gravimeter[2]

reasonable insulation from various source of vibrations, the key point is the mechanism to launch or drop the mass, i.e. an optical prism protected by a cart. The cart has the function to offer the necessary friction to the retaining system used to launch or drop the prism, without disturbing the optical alignment of the latter.

But it offers also the possibility to reduce the effects of the buoyant residual force, since the normal operating vacuum condition is 10^{-6} Torr. Authors[2] have reported correction-factor of buoyant force in the order of 5 μGal/Pa, partially compensated by the correction required for the wavelength-reduction in the operating vacuum conditions, 3 μGal/Pa. Thus the measure requires a total correction in the range of ~ 2 μGal/Pa. Moreover, the cart protects also against residual influences of the magnetic fields and other sources of noise for the measurements. The above mechanical problems are more complicated in case of R&F respect drop-devices. In fact the majority of absolute free-fall gravimeters are designed in drop-configuration to simplify the launching mechanics. But also to take advantage of the minimal errors produced by a practically zero value of the vertical component of its speed, which would influence the measure, but not the alignment of the interferometer, owing to the propriety of an optical prism indicated in figure 7.

R&F absolute gravimeters offer better performances, although these are more complicated to be realized from a mechanical point of view. In fact, R&F devices have a symmetric behavior, as visible in their characteristic curve reported in figure 5. The symmetric behavior has the benefit of compensating many errors[9] owing to opposite actions from upward (rise) and downward (fall) motion. Resistance of the residual air in the dropping chamber, magnetic fields and position errors will be also eliminated by the double directionality of the design.

The benefits of shorter dropping chambers and consequent increase of the measurement-time have been already underlined above. A drop only gravimeter, like the FG5-L, operates at a best-case rate of one drop every 2 s with a best-case duty cycle of 0.2s/2s or one tenth.

4. DESCRIPTION OF THE PROPOSED NEW GRAVIMETER

We propose in the following a possible improvement to the latest generation of portable absolute gravimeters, adopting a R&F configuration, reducing consequently the size while contemporarily increasing the measurement-period. We have also devised some extra features, in the attempt to improve the single-drop figure, trying to attain, at least theoretically, a global value better than ± 0.5 μGal/drop.

The device here proposed has essentially the following innovations:

1. Higher optical fringes-resolution, owing to a peculiar modification of the classic Michelson's Interferometer configuration
2. New design-concepts, minimizing the dropping height
3. New design concepts, reducing the "stop time" and increasing the "throw-rate".

4.1 Higher optical fringes resolution of the modified classic Michelson's Interferometer

The scheme of figure 2 is proposed, in order to develop a third-generation of laser gravimeters. The advantage of this configuration is that the displacement H_N corresponds to:

$$H_N = (1/2)\cdot(M + ½)\lambda_0 = (2M + 1)\,\lambda_0/4 \qquad (7)$$

Where M is an integer (= 0, 1, 2, 3…). The fringe-order in this case is $\lambda_0/4$, and its accuracy $\pm\,\lambda_0/8$. This represents an effective advantage because, with the same number of counted fringes, i.e. $N \equiv (2M+1)$, we find that $H_N = H/2$. In other words we have reduced the drop height of a Michelson's interferometer in half, without compromising in measurement-precision. Basically, if we have a drop-height of 35 cm with a R&F system, using a conventional Michelson's interferometer, then with the proposed solution we have a theoretical 17.5 cm dropping path with a considerable reduction of the related chamber. It is possible to consider feasible dropping-heights of 10 to 15 cm, thus matching with the size of transportable dynamic gravimeters. The advantages of shorter drop-height will be also beneficial to the measurement period rate and the instrument-precision, expressed in μGal/√Hz, as discussed above. Thus, the first claim that we propose a more precise and accurate gravimeter is satisfied, since in the DPMMI

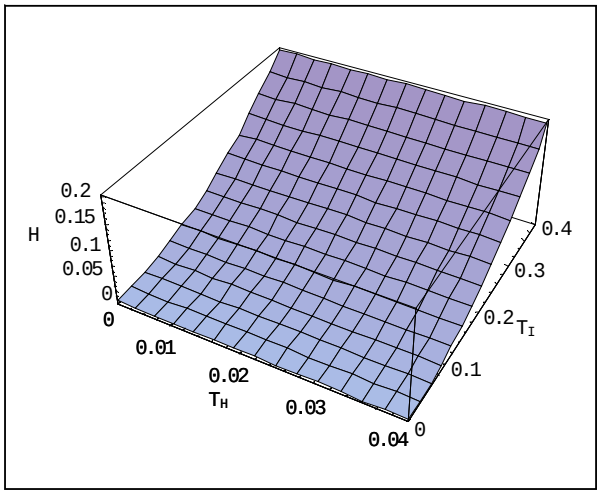

Figure 6: Surface graphic of H, drop height, in function of the total, T_I, and stop, T_H, times.

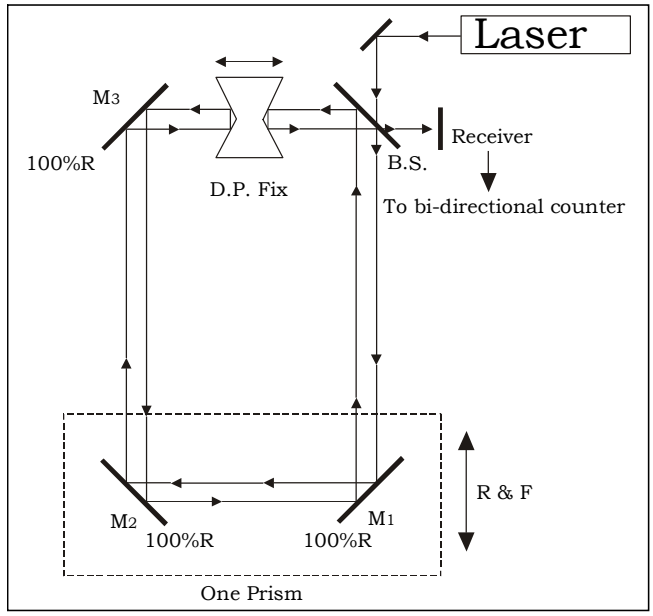

Figure 8: First gravimeter version based on the DPMMI.

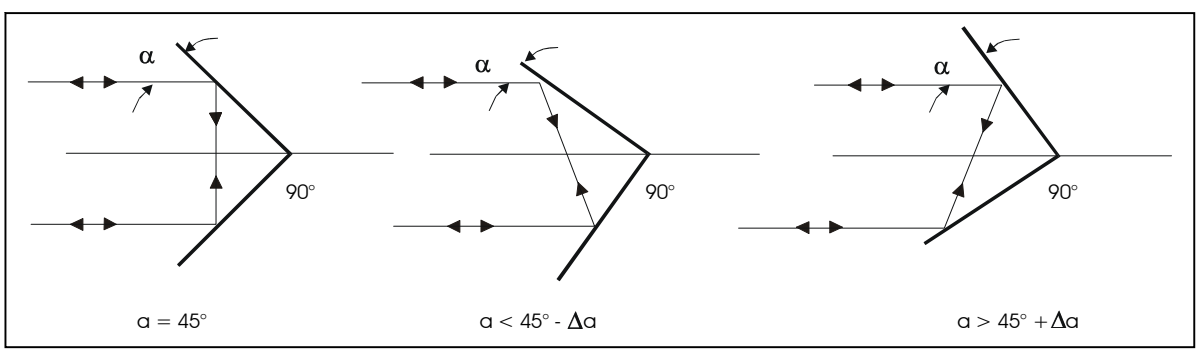

Figure 7: The propriety of the optical prism reduces misalignment errors.

case, the precision is $\lambda_0/4$, and accuracy is $\pm \lambda_0/8$.

4.2 New design concepts minimizing the dropping height

The adoption of the DPMMI introduces the possibility to reduce the effective height of the dropping chamber by half of the current devices, as demonstrated above with equation (7). The intrinsic accuracy of fringe-count of the proposed interferometer improves (by 1/8 factor) the figure of a classic Michelson's interferometer, thus giving an expectancy of ± 0.5 μGal/drop accuracy and precision of ± 1.0 μGal/drop.

We notice that the proposed DPMMI suggests the adoption of two interesting and perhaps quite "innovative" solutions, without compromising the newly introduced benefits. The ideas are shown in figure 8 and figure 9. Figure 8 shows a gravimeter-scheme close to the classic concept discussed above. The free-falling prism is represented by M_1 and M_2, which must be regarded as a single prism. This improvement can be adopted directly on the present gravimeters by simply introducing conveniently the double prism in the optical path in a kind of a retrofitting. The direct benefit expected in this case is the shortening by half of the dropping height and consequently an increase of the precision by the increase of the dropping-rate and the intrinsic higher precision of the DPMMI.

But the DPMMI offers a more interesting and alternative scheme to that of figure 8, which is shown in figure 9. In this case, the double prism is in reality formed by two separate prisms, P_1 and P_2. Using a dropping chamber shorter than any other dropping chambers, almost half of their falling height. Thus we can imagine developing a double launching system that throws alternatively P_1 and P_2, so that we obtain two benefits. The first benefit is that the dropping chamber is shorter and thus the advantages of the scheme described in figure 8 are preserved. But in this case, we can imagine an automatic system that controls the alternate launch and drop of P_1 and P_2 in order to reduce the duty-cycle between two subsequent drops almost to zero. Thus, in the case of the scheme described in figure 9, we enjoy the reduction by half of the dropping height and almost a *four times* increase of the dropping-rate. Infact we consider (a) two times, due to reduction by half of the dropping height and (b) two times, due to reduction to almost zero of the dropping rate duty-cycle by launching alternatively P_1 and P_2.

We notice that adopting the two-prisms solution gives, in itself, a kind of double-directionality to the system, so that we can consider rotating the branch of the interferometer containing the two prisms, while the other part remains fixed. This is possible without introducing sensible misalignments in the interferometer, due to the properties of the optical prisms already underlined in figure 7. In this way, the dropping chamber can be turned like a sand-clock. Quite interestingly, we may imagine to introduce a double mechanism so that inside the dropping chamber will be a double rise-and-fall launching system, while the sand-clock type of operation will ensure a further alternate drop regime.

In this way we may conceive an automatic control-system that alternates cycles of single-drop regime with those of rise-and-fall launches, synchronized with the continuous rotation of the dropping chamber. The advantage is that, by comparison, one may correct the systematic errors introduced by the launch-speed components that may interfere with the measure, as above discussed. Is is quite possible to develop dedicated software that controls all the functions of driving the rotations of the dropping chamber, the alternate dropping regime of P_1 and P_2 and handles, in parallel, the data acquisition. The idea for this is shown in figure 10.

The transfer function of the conventional R&F laser portable gravimeter, based on a classic Michelson's Interferometer, has the behavior already shown in figure 5. In fact, the transfer function in this case is expressed by equation (8):

$$I = (2A^2/Z)\mathrm{Cos}^2[(k/2) \cdot \Delta z] = (2A^2/Z)\mathrm{Cos}^2[(\pi/\lambda)(g/8) \cdot t^2] \quad (8)$$

where A is the laser-source irradiance (W/m^2), Z is the intrinsic impedance in free space ($Z = 377\ \Omega/n$, n is the refractive index of the medium, in case of vacuum n = 1), k is the amplitude of the propagation vector, $k = 2\pi/\lambda$. Equation (8) is the result of the application of the theory of propagation of electromagnetic waves interference, expressing the laser-light waves from the Maxwell equations in polar coordinates for the center of the interferometric pattern,

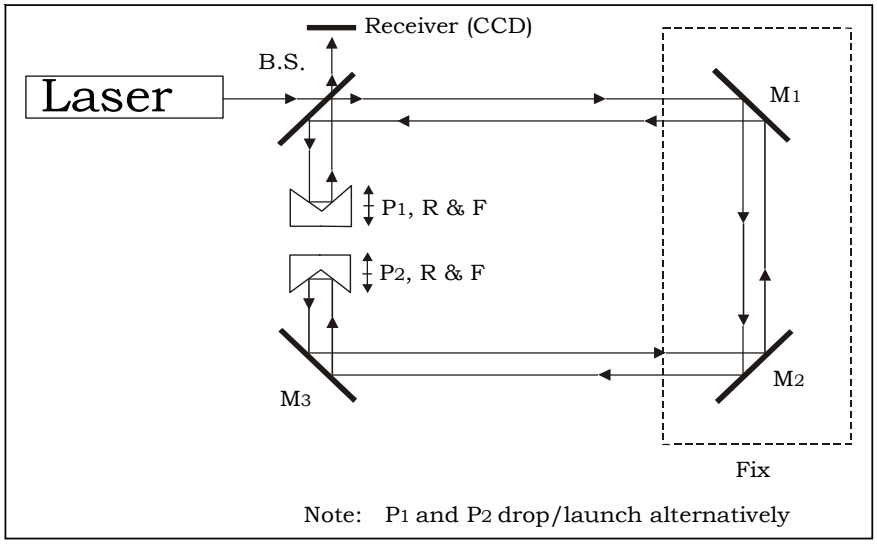

Figure 9: Second gravimeter version based on the DPMMI.

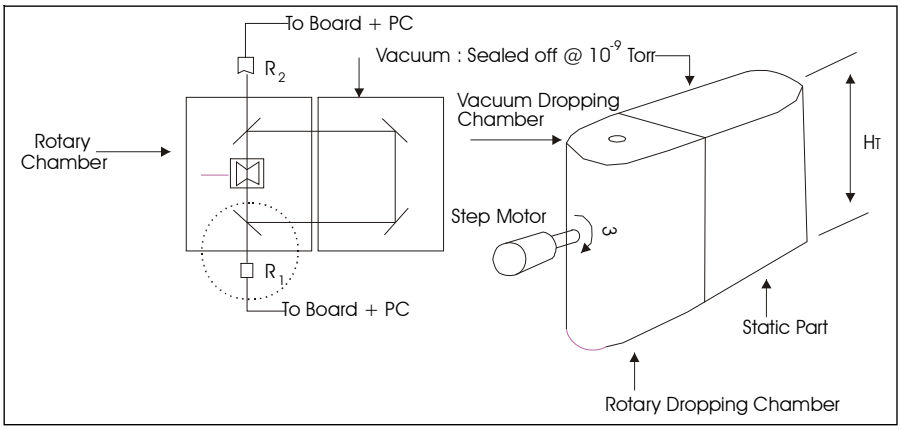

Figure - 10: "Futuristic" concept. For simplicity, beam paths are single lines and prisms shown not separated, as they must be to obtain optical fringes.

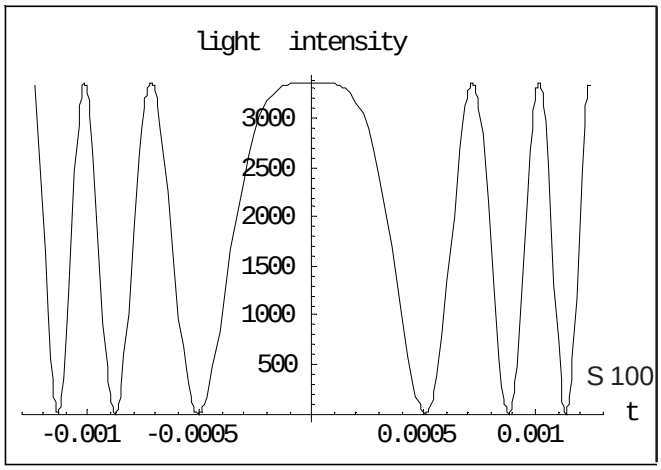

Figure - 11: Transfer function of an R&F currently available laser portable gravimeter.

r = 0. More particularly, equation (8) is obtained from the standard relation of the light-intensity of a classic Michelson's interferometer, available from literature[10], which is an acceptable approximation. In details, we have imposed in equation (8) that the beam path-difference, Δz, that generates the phase-shift to produce the fringes, is coincident with the dropping height, $H \equiv \Delta z$, and solving equation (1) in H, $H = g \times (t^2/8)$, assuming for simplicity $t^2 = T_1^2 - T_h^2$, which means not considering the inversion motion time, $T_h^2 = 0$, basically not of interest in a theoretical approach. After substitutions and manipulations, equation (8) is obtained. Equation (8) can be adopted to simulate the transfer-function of real cases, by simply substituting experimental data. Assuming an R&F device operating with a conventional Michelson's interferometer, we can substitute real parameters and values in equation (8) and then compare it with the transfer-function of the devices proposed in figure 8 and 9. For example, assuming working with a frequency-stabilized HeNe laser of 5 mW output power, with a 632 nm vacuum wavelength and a beam diameter at the source of 2 mm, a dropping height of 0.30 m, we find a transfer-function expressed by equation (9), whose behavior is reproduced here in figure 11 below.

$$I=3362.86445\cdot\mathrm{Cos}^2[(3.14\cdot 9.8)/(8.0\cdot 632.0\cdot 10^{-9})(t^2)] \quad (9)$$

Conversely, the following equation (10) shows the transfer function for an R&F laser portable gravimeter, adopting the proposed modified Michelson's interferometer with the same parameters of equation (9). The behavior of equation (10) is visualized in figure 12.

$$I=3362.86445\cdot\mathrm{Cos}^2[2\cdot(3.14\cdot 9.8)/(8.0\cdot 632.0\cdot 10^{-})(t^2)] \quad (10)$$

Comparison between figures 11 and 12 gives a clear idea of the advantages of adopting the proposed modified Michelson's interferometer in one of the two versions proposed above. In fact, for the same dropping height, the number of counted fringes is double for the proposed solution. This is clear evidence that the proposed configuration enables shortening the dropping-height by half and, consequently, enables increasing the throw rate. At half dropping-height, the transfer-function given by equation (10) overlaps the one represented in figure 10, which encourages us to assume, at least theoretically, that the class of precision of the instrument will be at least the same of any available R&F devices operating with a conventional Michelson's interferometer, but with higher accuracy.

Differentiating equation (10) as a function of the variable time, t, we obtain the theoretical intensity fluctuations in function of the time:

$$dI/dT= -1.6373\cdot 710^{11} t\,\mathrm{Cos}\,1.2172\cdot 510^{7} t^2\ \mathrm{Sin}\,1.2172\cdot 510^{7} t^2$$

We have drawn the corresponding diagram in figure 13. The diagram shows clearly that the shorter the R&F time-duration, the intensity fluctuations, which may influence the readings of the instrument, will not influence the measure.

Similarly, in the case of a conventional R&F gravimeter, the behavior of the intensity-fluctuations will be similar, but the system shows a better tolerance to relatively longer R&F times, as visible in figure 14.

4.3 New design-concepts, reducing the stop-time and increasing the "throw rate"

The systems described in figures 8 and 9 may effectively help in increasing the "throw rate" by a drastic reduction of the measurement-period, provided a suitable process-control is introduced. The process-control will also enable the fully automatic measurement procedure. In this case, the device appears to be, at least theoretically, an interesting candidate to become an effective *transportable* absolute dynamic gravimeter.

5. CONCLUSIONS

We have introduced a modification to the classic Michelson's interferometer, already described in previous works, by introducing a double prism. This second modified interferometer enables us to reduce by half the size of the dropping chamber, without compromising on the final precision and accuracy of the instrument. We have proposed two schemes that can give benefit of the shorter dropping chamber. The first scheme enables also increasing the drop-rate to

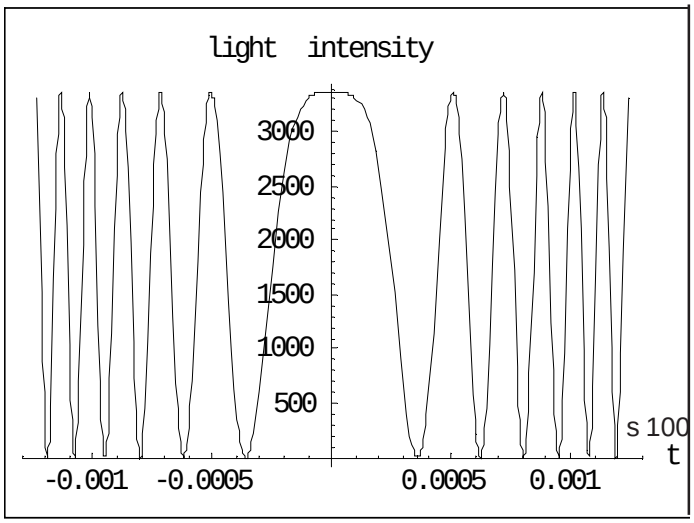

Figure - 12: Transfer function of the newly proposed R&F laser portable gravimeter.

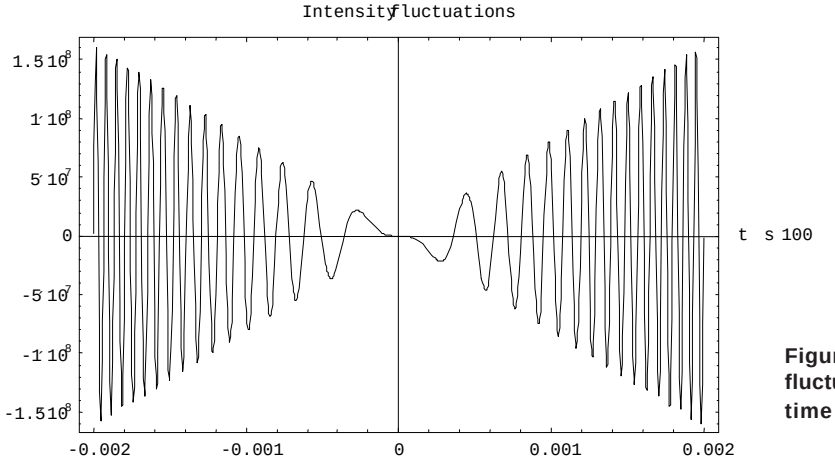

Figure - 13: theoretical intensity fluctuations in function of the R&F time for the proposed gravimeter.

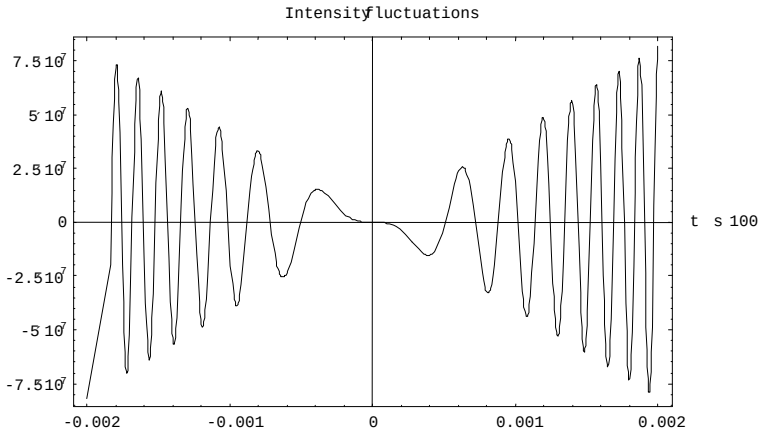

Figure - 14: theoretical intensity fluctuations in function of the R&F time for a conventional portable laser gravimeter.

further improve the final precision of the instrument on the averaged values.

The second scheme, with two prisms launched alternatively, enables us to increase the launching rate theoretically by four times. In order to get benefit from the advantages of the R&F and drop configuration and the alternate launch of the two prisms, combined together, we have proposed a "futuristic" scheme where rise-and-fall launches are alternate to simple drops, thus enabling mutual compensation of the systematic errors typical to each of the two configurations.

It is finally expected that improved frequency-stability schemes of laser sources and corresponding size-reduction will enable one to build very compact and transportable absolute gravimeters candidate, to be used in dynamic measurement conditions.

ACKNOWLEDGEMENTS

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GROWTH-POTENTIAL OF PAKISTAN'S WATER-RESOURCES AND THEIR IMPACT ON DEVELOPMENT

*Malik Muhammad Nazeer**

ABSTRACT

Pakistan has ideal and matchless God-gifted resources for its own overall development and a very decisive role in grabbing the earth globe out of the mouth of twenty-first century's environmental dragons, ready to swallow the entire life on it. Its location on the globe and its geographic position in the subcontinent, having the world's highest and biggest snow glaciers, containing the mountains, Himalayas and Karakoram, along with special pattern structure of mountain-wall on the north and the Indian Ocean, bay of Bengal and Arabian Sea around the Equator, led and followed respectively by largest recipients of solar-heat, the continents of Australia and Africa, on the its south has no match throughout the world. The mechanism having above- stated component parts causes heavy monsoon rains.

A sizeable share of these rain waters is received by Pakistan, which has the potential to store all or most of this water and use it not only for its agricultural and power requirements, but also for safely leading the world out of the crunching grip of environmental dragons of twenty-first century. Before highlighting the role of Pakistan in ameliorating deadly Global issues of exponentially rising global warming, environmental pollution, hole in the stratospheric ozone layer, droughts and resulting social and economic problems, it is worthwhile to properly estimate the size and mechanism of its resources and their direct impact on its local development. This aspect is fully discussed in the present work, as a preface to its real and ideal roles, which will be highlighted in the subsequent attempts.

INTRODUCTION

The earth's rotation, supported by the enormous amounts of solar energy received by Australia and Africa with large temperature and pressure-gradient between these main-lands and the Oceans, produce large wind currents, resulting in monsoons which carry water-vapors from the Indian Ocean, Bay of Bengal and the Arabian sea towards the Indian sub-continent. The high Himalaya mountains in the north of the sub-continent and the Karakoram range in the north-west of Pakistan enable these winds to form loops and discharge water-contents, as rain, and provide huge water-storage for the sub-continent in the form of snow. Although Pakistan is very lucky to have numerous dam-sites to store large quantities of this two-to-three month supply of monsoon rain-water and regulate it for its perennial irrigation and electric power generation purposes, but unfortunately these water-resources are not being fully utilized. Proper planning and execution could help increase the water-resources more than twice, the agricultural product by four to five times and hydro-electric power-generation capacity by a factor of about ten. These resources, their location, their size and mutual compatibility, when viewed in the perspective of Pakistan's development and particularly in that of global challenges, at once bring into mind the position that Nature has intentionally created this entire system for the (complete) solution of Mankind's deadly problems of 21st Century. The system is ready to work, but it needs the effort of Mankind to start it. Its starting key, however, is the well planned construction of its water-storage, power-generation, irrigation and drainage systems, and Mankind has to do it collectively at any cost, putting aside all the differences, whatsoever, for its safe existence on the globe. Naturally, the industrial countries and producers and user of fossil fuels have a large share in contributing to and fuelling the global problem and they should, accordingly, be the major contributors of the cost involved in remedial operations. The UNO have the opportunity to do the most-wanted role of planning, supervising, financing this activity and collection of the due contributions.

MECHANISM OF WATER-RESOURCES

The rotation of the earth about its polar axis at a speed of about 1000 mph, exerts centrifugal force on the atmosphere, which along with its vertical component are zero at the poles and maximum at the Equator, while its horizontal component, directed towards Equator, is maximum at 45° latitude, but zero both at poles and Equator, as shown in Fig 1(a.b.). The horizontal component of centrifugal force pushes the winds towards the equator on the surface of earth

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and the solar-heat forces it towards the poles in the upper atmosphere. In summer, this movement is further amplified by the solar heating difference in the two hemispheres, due to 66.5° inclination of the earth's polar axis to the plane of its rotation around the sun. Therefore, during the summer, the winds in the form of Monsoon are forced from Indian Ocean and Bay of Bengal to Indian sub-continent [1,2] by the temperature difference of the two hemispheres, and by pushing of the East African ridges and directing the dragging air, due to spinning of the earth about its polar axis. Their post-equator route is mainly through the Bay of Bengal, directed by the earth's polar rotation[3]. These winds are further redirected towards Nepal and northern areas of Pakistan, particularly the Kashmir region, by mountain-wall of Himalayas and Karakoram on the north of Indian subcontinent (Fig. 2). The Pattern of these mountain-ridges [2,4] gives rise to local cycling of the Monsoon winds, causing rain in Bangladesh, India and Pakistan. Guided by northern and north-western mountain wall, augmented by the horizontal component of centrifugal forces (due to earth's rotation) and further directed by land and sea trading across Indian sea-shore, the cycle is completed across Pakistan, Iran, Saudia and Ethiopia onward. The Equatorial areas of Africa and Australia provide necessary heat-energy to these winds for their water- vapour charging from the Indian Ocean.

In winter, low pressure is developed behind the Himalayas, due to the earth's spinning, by the trading of the winds between the earth's hemispheres and due to different solar heating effects on land and sea. This forces the Eurasian, Mediterranean and Caspian sea winds to follow the route shown in Fig. 2, which give rise to local winds counter-clockwise circulation [5] in and around Punjab. For the rest of the year, the winds normally creeps from south to north and are guided by the mountain-ridges towards Kashmir. Except the Monsoon, the winds are normally dry, and their main source of feed for rain and snowfall is local evaporation of water from rivers, lakes, irrigated land and plants, as shown in Fig. 2,. Thus, more supply of water to irrigated area will result in more rain and snowfall during this dry season.

The scenic situation of Australia and Africa on the two sides of Indian Ocean, around Equator; a smooth passage of Bay of Bengal and the mountain enclave, with special guiding-pattern on the north of Subcontinent, for guiding, tracking and de-watering of the generated monsoons; one of the longest perennial rivers Indus, with a number of feeding tributaries and large snow-glaciers of World's highest mountain-ranges and with number of large deep valleys for storage Dams; large fertile planes with suitable natural slope located at very suitable latitude for availability of required solar heat; worlds largest solar-heat reservoir-Africa and Middle east - at its south west and special local and global wind routes; all this makes Pakistan, ideal and matchless throughout the world.

LOGIC BEHIND PAKISTAN'S WATER STORAGE CAPACITY

The main contributor of Pakistan's water resources are the Indian ocean, the Arabian sea and the Boy of Bengal in the Monsoon season(Fig. 2). The evaporated water from these regions is carried by winds towards the Himalayan ranges and then is directed westward. This brings heavy rains and snow in the north and northwest of Pakistan.

It is estimated [6] that Pakistan has annually an average of 143 (Min.110,Max.180) MAF(Million Acre Foot) water-flow capacity. About 30 MAF flows from September to May, while the rest of 113 MAF flows generally in the peak rainy season from June to August (Fig.3). If the irrigation system is fully developed to use all the 143 MAF of available flow of water, even then the irrigation demand during peak-flow season, as shown in Fig. 3, can hardly be 25 MAF instead of 36 MAF because of the local heavy rains. Under these conditions, about 88MAF of water will be available for storage. The water-storage system should, however, be designed for the maximum water- flow rather than for the average flow i.e. storage capacity should accommodate about 135 MAF (180-30-25). The water-storage capacity of existing dams is only 13 MAF, i. e. 8 MAF of Turbela and 5 MAF of Mangla. Therefore, about 77 MAF based on average and 122 MAF based on Maximum flow, could further be stored, which at present flows down to the Arabian Sea.

POTENTIAL OF GROWTH IN WATER-RESOURCES OF PAKISTAN

The second main contributor to source of water is Pakistan's irrigation system (Fig. 2 & 3). About 80%of

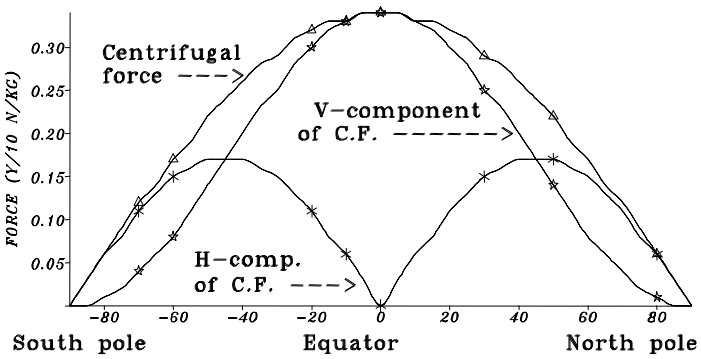

Figure - 1(a): Centrifugal force due to earth's rotation and its vertical & horizontal component along a longtitude

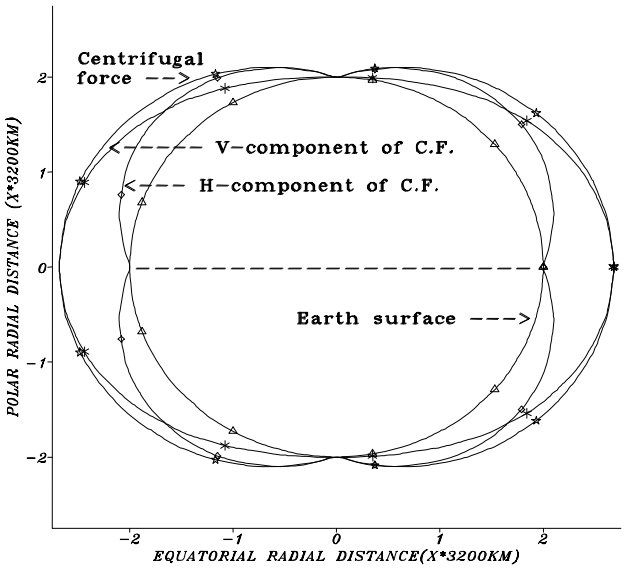

Figure - 1(b): Centrifugal force due to earth's rotation and its vertical & horizontal components

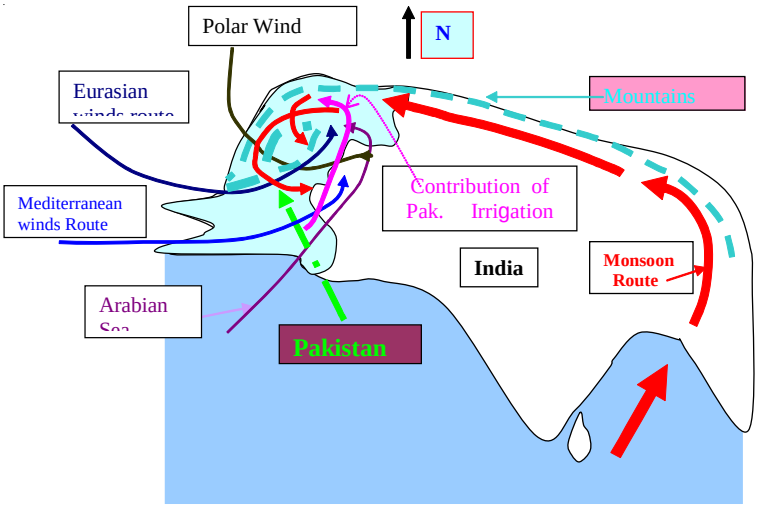

Figure - 2: Wind routes in the subcontinent and especially across Pakistan

62 MAF (30+13+19) of water, which is presently fed to the agricultural lands, as shown in Fig. 3, evaporates and about 80% of this evaporated water falls back in the form of rain and snow in the catchment areas of Pakistan's rivers. Therefore, about 40MAF out of 143 MAF available flow is due to the feedback contribution of 62 MAF, which is being used for agricultural purposes. If all the 143 MAF could be used for agricultural purposes, then the local contribution to rain and snow could be increased from 40 MAF to above 92 MAF i.e. the 143 MAF available quantity of water could be increased to more than 195 MAF. An iterative computer model, based on the average flow, as presented in block diagram of Fig. 4 shows that water resources can be increased from 195 to 250 MAF, if 110 MAF water-storage and corresponding irrigation system is properly developed and the drained underground water is re-circulated (Figs. 5 & 3). It will be very interesting to note that, due to ideal environmental location of Pakistan, the local contribution to the flow-resources is quite reliable, as compared to the global contribution, and thus the development in this field will minimize the fluctuation of flow as well.

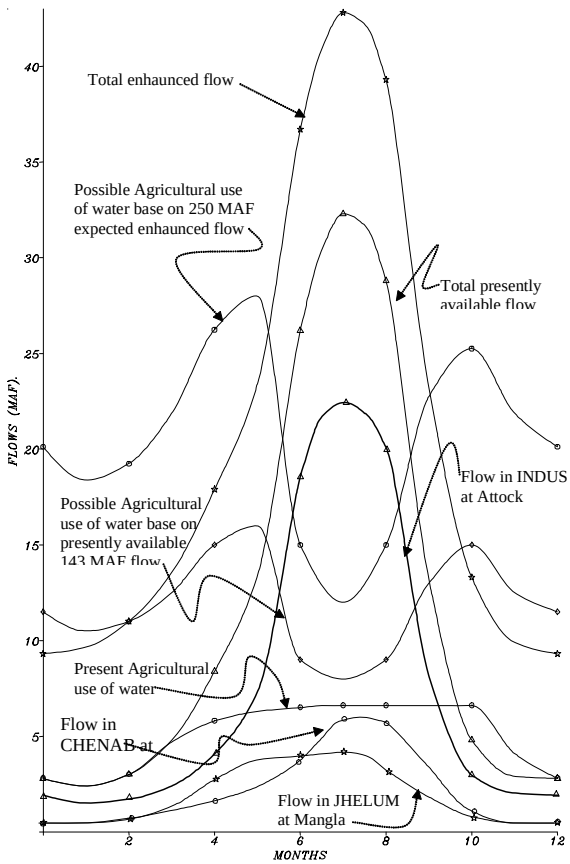

Figure - 3: Present and predicted water-flow in Pakistan rivers and its present and ultimate irrigation usage, based upon both available and predicted flow

As is shown in graphs of Fig. 5, with 110 MAF storage capacity, the requirement of irrigation and drainage recycling system handling-capacity is 330 MAF and it will yield 85MAF of local rains, 145MAF feed to flow- resources by local recycling, with 250MAF net flow resources. Thus, the development outlined above will result in tremendous growth in the water-resources of Pakistan, with ideal solution to a number of extremely critical local and global issues. If an optimum storage, irrigation and drainage system is developed, all the enhanced available water-flow may well be utilized for irrigation and all of it will have to be evaporated to avoid water-logging-of course, the absorbed quantity will have to be extracted through drainage- system and forced to evaporate indirectly (through re-circulation) or directly (using barren lands) for blocking the global warming and for its maximum utility in growth of water-resources.

STORAGE EFFECTS ON AGRICULTURE

The country's agricultural output is based on 62 MAF (80 MAF, including local rains) feed of water. With the enhanced resources of 330MAF(370MAF), the irrigated area may increase 5 times, with sufficient supply, and hence the agricultural output may well increase up to 7 times. All the remaining plains area of Pakistan (may it be southern Frontier, may it be southern and Northern Punjab, may it be eastern, southern and western Sind or may it be all the plain area of Bluchistan) may quite sufficiently be irrigated and it may provide the matching part-the area required by the proposed system to be irrigated. The resources, when fully developed, could even enable Pakistan to sell it's extra water to India for its irrigation of Rajistan area.

STORAGE EFFECTS ON HYDRO-POWER

The quantity of water available and its gradient are the two important basic factors for hydro-power generation. God has gifted Pakistan with both of these factors, adequately. At present, it is being largely

wasted. Most of the available water (143 MAF) flows down from a height of about 7000-8000 ft.[5]. Pakistan is also very lucky to have many reservoirs and dam-sites along its rivers Indus, Jhelum, Kabul, Swan and Hero, which could be used for storing and regulating water for irrigation and power-generating purposes. Some of the dam sites are Skardu, Kalabagh, Bhasha, Chillas, Dasu, Gilgit, Dhoke Abbaki, Dhoke Pathan, Geriala, Mukhad, Azad Pattan, Mong Rasul, Sehwan Mansher, Chitral and Thal. These dams could store and regulate the water-flow for agricultural and power-generating purposes, over a long period; but to achieve this goal, bold and wise steps need to be taken as early as possible. The average water-head for 143 MAF is about 5,000 ft. Therefore, an estimated peak power-generation capacity would be 5000X143 or 715000 MASF (Million Acre Square Foot). If 50% of this could be feasible, due to technical reasons, even then Pakistan could generate 360,000 MASF (42,000MW) of hydro-electrical power. Presently, only 62 MAF with an average head of 500 ft. is being utilized for power generation, i.e. 62X500 MASF or about 3,600 MW, which is only about 9% of the total capacity. Therefore, with proper development, upto 10 to 12 times enhancement in the present hydro-power level could

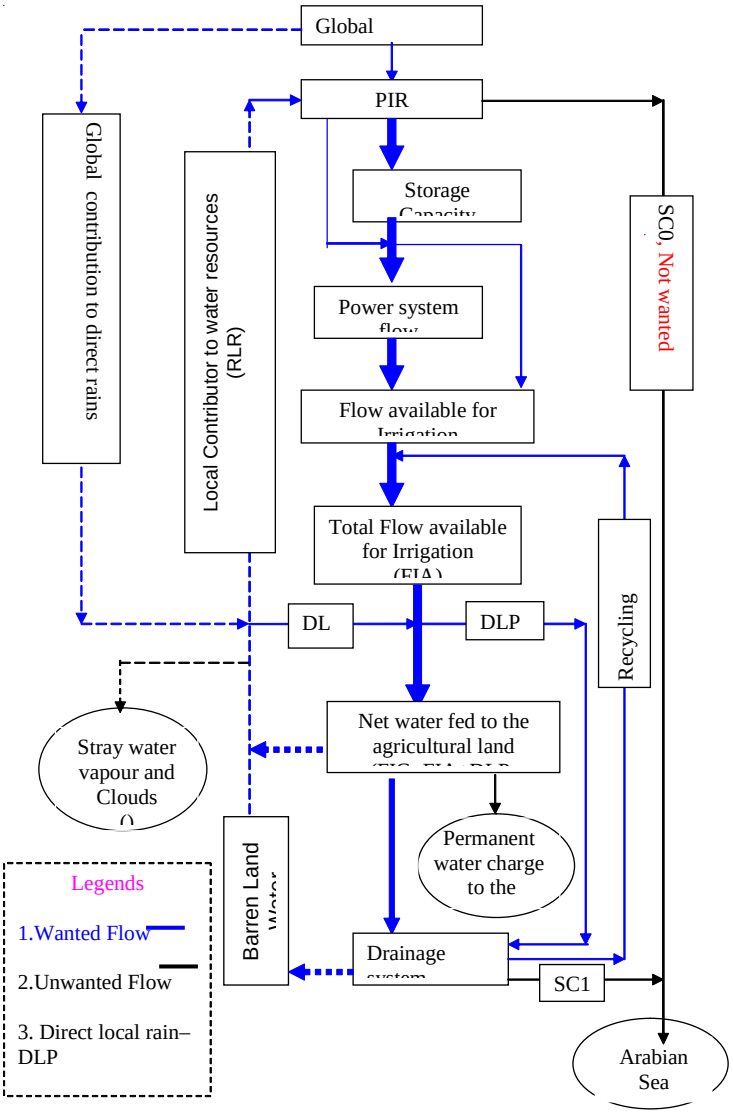

Figure - 4: Suggested Water-Cycle of Pakistan and Block Diagram of the Computer-Model

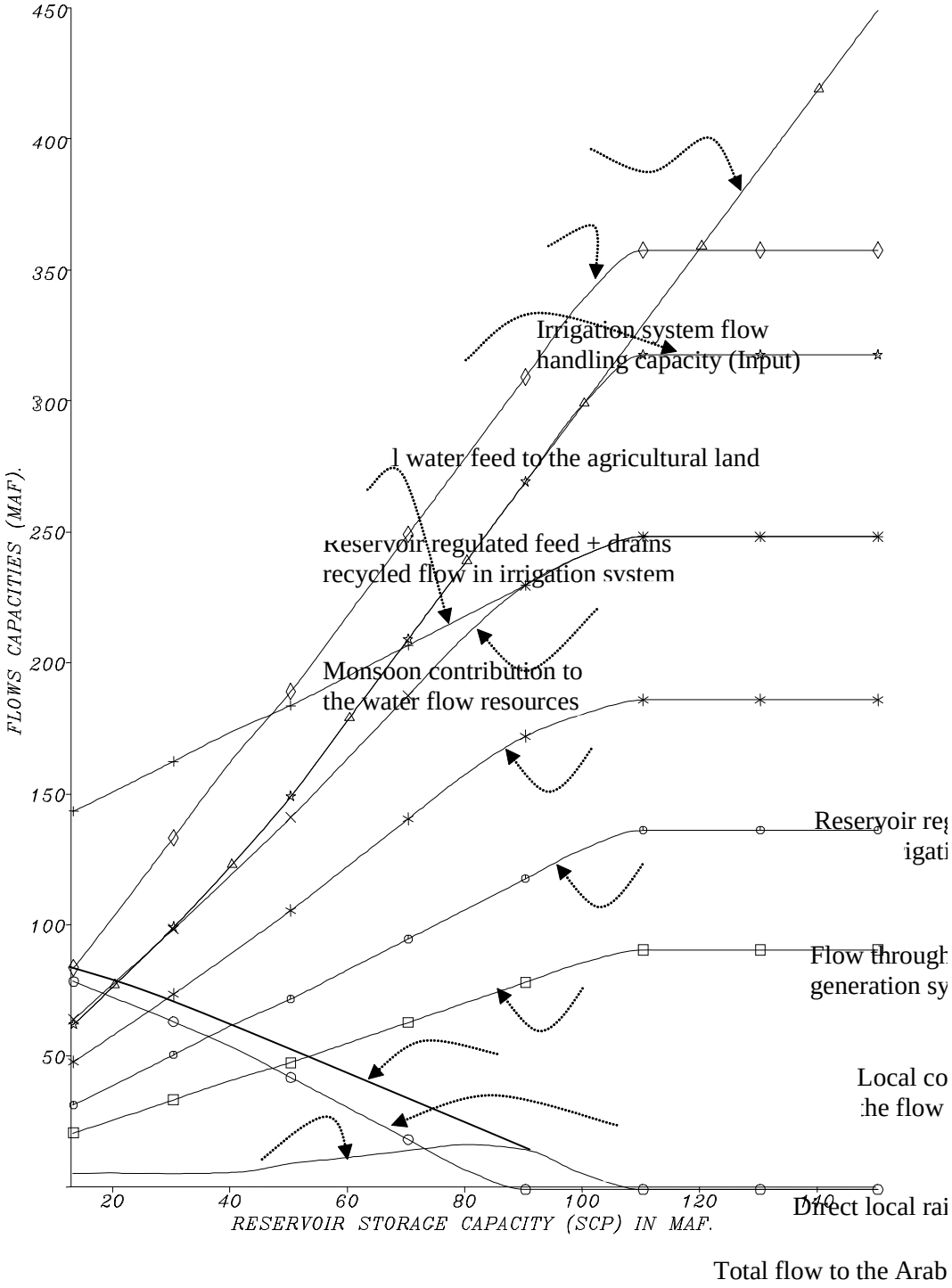

Figure - 5: Reservoirs Capacity Effect on Related Flow Quantities

well be achieved. It is suggested that, in the first stage, 10 to 12 dams with sufficient storage and power-generating capacity should be constructed, to meet the country's present power and agricultural demands.

Unlike costly petroleum, oil, gas, and coal sources, water is not consumable and is available free of cost; also running cost of hydro-electric plant is low, as compared to other sources. This is why the hydro-electricity is much cheaper, as compared to petro-chemical or nuclear power. Moreover, there is no risk of source-exhaustion, atmosphere pollution; and it is free of any radiation hazards. This will also result in producing a well regulated supply of all the available water to the irrigation system and would be a great help for the economic stability of Pakistan, by boosting the agricultural and industrial output and employment, by creating new opportunities in agriculture, industry, power and irrigation sector.

RECOMMENDATIONS

In order to get full benefit of the water-resources, Pakistan has got to develop its own missing-link in the water-cycle shown by thick blue lines in Fig. 4, i.e. to develop adequate storage, irrigation, power-generation and water-drainage systems. Even the wastewater should be forced to follow the thick blue dotted route (Fig. 4), using the barren lands at the downstream side. In order to achieve this goal, sufficient funds, machinery, materials, manpower and expertise are locally available or can possibly be made available through UNO, by highlighting its impact on the terrible global issues of earth's heating, pollution, ozone-layer depletion, petroleum exhaustion and tremendous rise in oceanic levels, etc. Therefore:

Firstly, the overall Planning for surface-storage of available water for power- generation, irrigation, and flood-control, with its time-bound execution, should be started. This planning should be done with mutual cooperation between related departments and should be based upon thorough objective study and analyses of overall aspects, results and consequences.

Secondly, the Execution-Phase should immediately be started for the projects already designed and awaiting execution, like the KALABAGH DAM. If this sector is developed with well-organized planning, not only power and agricultural output of the country, but also aqua-cultural and industrial output will be boosted many times.

Thirdly it should be pointed out here that **multipurpose Large dams are vital**, very cheap, both in construction and in operational cost per unit of their output. It is childish to talk of small dams in comparison with these, just like accepting a number of very beautiful and cheap small cars against an actual Mercedes car. Also, **reclamation of additional storage-facility, by raising its hight further, in the existing dams is extremely dangerous,** and government should **refrain** from it, until and unless 3-4 non-military organizations, expert in design of dam and allied critical facilities, should thoroughly analyze the initial design independently and all confirm its feasibility. After all, it is a multi-billion dollar costly dam designed and constructed only for the present maximum water-level and also involves question of life of millions of peoples living down-steam. The de-silting like that of large harbours may rather be considered and the collected silt may be downloaded in the dead volume pockets or in the side-valleys, reclaiming these for agriculture.

KALABAGH Dam Vitality: The multipurpose KALABAGH dam is vital for southern Frontier and Bluchistan irrigation and very cheap, very easy in construction and has number of merits, as compared to its sisters other dams, as stated below.

In view of additional 97 MAF storage requirement, all the possible dams need to be constructed and Pakistan should start several of them, in parallel, as much as its resources so permit. Thus, within 2-3 years, 4-5 dams may be in various phases, one after the other, utilizing the same "men and machinery phase-related resources" successively on various dams. Hence, there is no tie in between any two or three sites what-so-ever. Kalabagh, **a multipurpose dam with irrigation and flood-control priorities**, has many merits and its priority-construction is vital under number of aspects. In this connection, a review of following few points is worthwhile.

i) It have gone through a number of initial phases and is ready for construction right now;
ii) Its storage capacity may be comparable with many other sister dams, yet in power-generation it has no match at all. All the storage of dams

upstream will directly add to the flow through its power-generation turbines, running always at optimum output and, in this respect, it has no match at all. It is not costlier than any competitor, yet, even if it were 4-5 times costly than the competitors, it wouldl soon payoff its whole price within a few years.

iii) Tarbala and Warsak Dams, being upstream, It has little risk of silting or sedimentation and in this respect, it does not have any match too. The de-silting option in this dam construction has no need to be considered. It has additional storable flow, due to its location downstream of rivers Kabul, Swan and Hero.

iv) Adequate supply of Irrigation water to Southern plain area of Frontier province and Bluchistan can be possible only with its construction. It can provide most quick and qualitative control on floods downstream of Kalabagh, due to flood in Rivers Indus, Sawan, Hero and Kabul and in this respect has no competitor.

v) Being right at the neck of irrigation water distribution system, it can relieve Sind and Nothern Punjab of Indian-based flood-damage, by providing most quick, direct and effective control on water-flow management in the irrigation-system and thus enable Pakistan to take irrigational benefits in the above stated areas from these floods too, in place of their damages.It can boost the agricultural output of District Kohat, Bannu, Mianwali, Chakwal, Attack and Mardan, through favourable change in the climate and frequent rains, and has no competitor in this respect too.

vi) Mobilization of construction materials, Machinery and Manpower may be easiest, cheapest and quickest.

vii) Power produced can most easily, quickly and cheaply be brought to National Power Grid systems.

viii) It is at a safe distance from the seismic epi centers and has no match in this respect also.

These aspects make Kalabagh a vital construction and affix it on the top priority. In the real sense, Kalabagh is the lifeline and soul of Pakistan's economic existence and its priority construction is vital in any case.

The controversies over its construction are all of childish standard and mostly baseless and, generally, not directly on Kalabagh, rather on any storage dam.

CONCLUSIONS

Utilizing maximum water-storage would certainly help regulate country's water-needs to increase the agricultural products and make Pakistan self-sufficient in food. This should also increase the Hydro-electric energy, to meet the much-needed demands of electricity which, in turn, helps the industry to grow. It may even turn out that if most of the dam sites available in Pakistan could be constructed to generate Hydro-Power, then Pakistan could even sell electricity. Above all, this will create millions of jobs and could amicably solve Pakistan's ever-rising unemployment problem. If Pakistan's presently available water resources could be fully and properly utilized, then the following results can be achieved;

- Four to five times increase in the irrigation land.
- Six to Seven times increase in the agricultural output.
- Ten to twelve times increase in hydro-electric power.
- Eight to ten times increase in the industrial output.
- Millions of job opportunities.

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GEOSTATISTICAL TECHNIQUES AND APPLICATIONS FOR MANAGING DEGRADED SOIL FOR SUSTAINABLE PRODUCTION

*Amanullah Bhatti**

ABSTRACT

Geostatistics deals with characterization of spatial dependence of measured soil-properties and helps to predict the values of the properties at unsampleld locations. Spatial patterns identified by geostatistical techniques are used to develop variable rate strategies for the sustainable management of fertility, and salinity/ sodicity of soils. This paper presents examples of using geostatistical techniques to identify and determine the magnitude of spatial variability of soil- properties and develop variable-rate management-strategies for fertility, salinity/sodicity, and mapping of degraded soils, for sustaining their productivity.

INTRODUCTION

Geostatistics is a branch of applied statistics that focusses on the characterization of spatial dependence in the measured variable or variables. It is used to model the spatial dependence of regionalized variable(s) or spatial variability of soil-properties, to interpret spatial patterns and predict values of the attribute(s) at unsampled locations. All the statistical procedures used for analysis and estimation of spatially dependent variables are collectively known as "geostatistics".

Spatial variability of soil-properties means that the sample-value of a soil-property gives some information about its neighbouring data point. In other words, it means that the sample values are not independent of each other but are correlated as a function of distance. Traditionally, it is assumed that the soil-properties are randomly distributed.

GEOSTATISTICAL TECHNIQUES

The basic tool of geostatistics is known as semivariogram analysis which is used to identify and describe the extent of spatial variability of regionalized variables.

i) Semivariogram Analysis: Semivariograms are developed to determine the structure and magnitude of spatial patterns of various measured soil-properties. Semivariance, r(h), as a function of separation distance (lag, h), is computed using the expression:

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [Z(x_i) - Z(x_{i+h})]^2 \quad \ldots\ldots \text{Eq. 1}$$

where n(h) is the number of samples separated by a distance h and Z represents the measured value for a soil property.

Ideally, the semivariance equals zero at h=0, since no variation in sample values is expected for measurements made at a given location. As the separation-distance increases, the semivariance function will typically increase, because samples become more poorly correlated (the variance increases). At a critical distance, known as the range, the sample pairs will cease to be correlated and values for the semivariance remain constant at a value known as the "sill", as separation distance continues to increase. Samples separated by distances greater than the range exhibit random variation (Fig.1).

For a quantitative description of these features, it is useful to fit standard models to the semivariance functions. Typical standard semivariograms include linear, spherical, and exponential models. Model-selection is usually based on a criterion of goodness of fit, which, in our case, involved fitting the model to data using non-linear least-squares methods. Expressions for each of the above models are given below:

Linear model: $\gamma(h) = C_o + Bh$ ……Eq.2

Spherical model: $\gamma(h) = C_o + C_1 [1.5(h/a) - 0.5(h/a)^3]$ $0<h<a$…Eq.3

$\gamma(h) = C_o + C_1$ $h>a$……Eq.4

Exponential model: $\gamma(h) = C_o + C_1 [1-\exp(-h/a_o)]$……Eq.5

In these expressions, h is the separation-distance between observations, a is a model-parameter known as the range, C_1 is a model parameter which equals the "sill" minus the "nugget", and C_o is a model parameter known as the "nugget". For the linear model, B is simply the slope of the line for a plot of semivariance versus separation distance. For the exponential model, a_o is approximately equal to a/3. Physically, the "sill" is approximately equal to the total sample variance and is

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the maximum value of variance which the model attains at large separation distances. Physically, sample observations separated by distances smaller than the range are statistically correlated to one another, while measurements separated by distances greater than the range are *not* correlated (Fig.1). Classical statistical methods can be applied to the data only if the range has a value which is smaller than the closest sampling distance.

Ideally, the experimental variance should pass through the origin when the distance of sample-separation is zero. However, many soil-properties have non-zero semivariances as h tends to zero. This non-zero variance is called the "nugget variance" or "nugget effect". It represents unexplained or "random variance", often caused by measurement-errors or variability in the measured property, which was not detected at the scale of sampling.

ii) Kriging: The parameters of semivariogram are used for interpolation of soil-properties at unsampled values. This procedure is called "kriging". Kriging is a method for making optimal, unbiased estimates of regionalized variables at unsampled locations, using the structural properties of the semivariogram and the initial set of measured data. A useful feature of kriging is that an error-term, expressing the estimation-variance or uncertainty in estimation, is calculated for each interpolated value. Kriging differs greatly from linear-regression methods for estimation at unsampled locations. Whereas a regression-line never passes through all of the measured data-points, kriging always produces an estimate equal to the measured value if it is interpolating at a location where a measurement was obtained.

The basic equation for interpolation by kriging at an unsampled location x_o is given by:

$$Z_k(X_O) = \sum_{i=1}^{n} a_i Z(X_i) \quad \text{.....Eq.6}$$

where n is the number of neighboring samples and a_i are weighing factors for each of the $Z(X_i)$. The weighting factors for neighboring measured points are constrained to sum to unity, i.e.:

$$\sum_{i=1}^{n} a_i = 1 \quad \text{.....Eq.7}$$

Application of Geostatistics to soil-properties: Geostatistics techniques can be used for the following:

- To determine the nature and extent of spatial variability of soil-properties and to identify their spatial patterns;
- Fertility-management of spatially variable soils, based on spatial patterns in soil-fertility and crop-productivity, to avoid over-fertilization and under-fertilization;
- Soil-sampling schemes, based on prior information of spatial patterns of soil properties;
- Environmental studies;
- Mapping of soil-fertility and soil, salinity/sodicity.
- Management of salt-affected soils, based on spatial patterns of salinity/sodicity.
- Design of field experiment e.g.
  - Directional patterns - blocking
  - To determine optimum plot-size;
- Statistical analysis of field experiments, e.g.
  - To identify yield-patterns or trends in field-experiments and presence of correlated errors.

PAST RESEARCH WORK ON THE USE OF GEOSTATISTICAL TOOLS IN PAKISTAN

Geostatistics is a quite new field to the Pakistani Soil Scientists and has been used on a very small scale in Pakistan. A course in Applied Geostatistics was introduced at M.Sc. Hons level in the Department of Soil Science, NWFP Agricultural University Peshawar, North West Frontier Province of Pakistan, in early 1990s. Geostatistical techniques were used to study the spatial variability of soil properties of degraded soils for their fertility and/or salinity/sodicity management, development of soil-sampling schemes, and mapping of soil-fertility and soil-sodicity. A brief review of the research work in this field, especially with regard to the management of degraded lands, is presented here.

1. Fertility management of eroded lands

A management-strategy of variable-rate fertilizer-application was developed to match the fertilizer-rates to the spatial patterns in crop-productivity on an eroded land at Thana, Malakand agency, NWFP, Pakistan. Landscape at the study-site (Fig.2) is characterized by steep land and its slope faces towards a stream. Relative

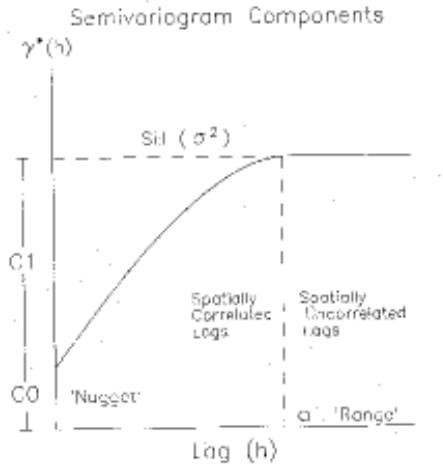

Figure - 1: Components of a Semivariogram

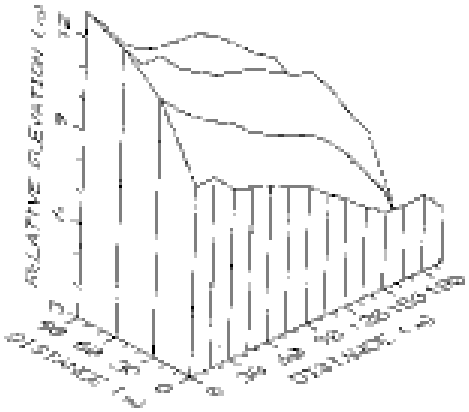

Figure - 2: Relative Elevation of Sampling Locations of Four Transects

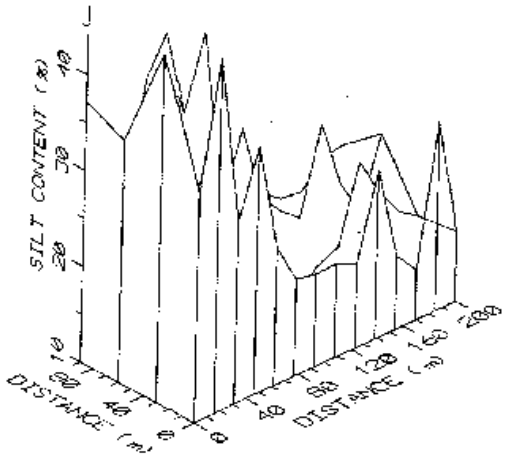

Figure - 3: Variation in Silt Content of the Field

elevation of the sampling locations ranged from 3.14 to 12.82 m. Most of the soil-properties had a very high coefficient of variation (Table 1). This high variability in soil-properties and wheat-yield is a function of position on the landscape and was *not* random. Silt content (Fig.3) and clay content was higher at upper slope positions, and sand content at lower slope positions. Similarly, organic matter was lower at top slope positions, as compared with bottom slope positions. Based on these results, the use of classical statistical procedures was not sufficient to describe and characterize variability in any of the properties.

Geostatistical technique of semivariogram analysis was used to identify and describe the spatial patterns of soil-properties and wheat-yield. Omnidirectional semivariograms were developed for each property and the parameters for the best fitting linear models were estimated (Table 2).

Table-1: Descriptive statistics of soil-properties and wheat-yield

SOIL PROPERTIES	MEAN	MINIMUM	MAXIMUM	CV(%)
Organic matter (%)	0.32	0.12	0.66	34.66
Lime content (%)	5.34	3.05	14.25	46.98
Soil pH	7.29	6.60	7.90	4.88
AB-DTPA ext. P ($mgkg^{-1}$)	2.68	1.35	3.90	23.78
AB-DTPA ext. K ($mgkg^{-1}$)	47.69	32.00	86.00	24.39
AB-DTPA ext. Zn ($mgkg^{-1}$)	0.51	0.28	0.83	24.55
Relative elevation (m)	8.55	3.14	12.82	25.29
Clay content (%)	2.05	0.40	3.95	55.79
Silt content (%)	25.82	14.20	47.14	34.12
Sand content (%)	72.13	50.76	83.60	12.43
Grain yield ($kgha^{-1}$)	3542	1000	6500	37.94
Profile available water (cm)	14.19	9.60	17.82	14.60

Table-2: Summary of parameters for semivariogram models*.

Property	Omnidirectional		
	Nugget	Slope	R^2
Organic matter (%)	0.0082	0.00004	0.64
Lime content (%)	1.2637	0.0519	0.96
Soil pH	0.0892	0.0005	0.71
AB-DTPA ext. K ($mgkg^{-1}$)	63.35	0.7151	0.71
Clay content (%)	0.5969	0.0115	0.86
Silt content (%)	16.257	0.6317	0.94
Sand content (%)	23.017	0.5717	0.94
Grain yield ($kgha^{-1}$)	1502900	2987	0.47

* Linear model

Spatial patterns of the potential-yield, calculatedfrom the lime-content, were used to divide the field into zones with low (< 3400 kg ha^{-1}), medium (3400-3600 kg ha^{-1}) and high productivity (> 3600 kg ha^{-1}). Potential wheat-yield of each zone was used to determine the N-fertilizer requirement for that zone, using the following expression:

N fertilizer (kg ha^{-1}) = [(Potential yield x % N in grains) - total mineral soil N (kg ha^{-1})]/0.5,

where a factor of 0.5 is the fertilizer-use efficiency of wheat.

Using this expression, the following rates of fertilizer N were determined, along with proportion of the area for that particular rate (Table 3). These rates were applied to wheat in different zones (Fig.4) and compared with the uniform rate of fertilizer application.

These results (Table 4) showed that the variable rate of fertilizer proved more economical, used less fertilizer and also reduces environmental pollution of groundwater and surfacewater.

2. Reclamation of salt-affected soils (sodic soils), using variable rates of gypsum.

A reclamation strategy for salt-affected soils (sodic soil) was developed, using variable rates of gypsum for different management units in a large field. Soil pH of the study site ranged from 7.4 to 9.0, EC ranged from 0.35 to 4.90 with a mean of 1.64 dS m^{-1} and a coefficient of variation of 49%. The range for GR was wide, from 1.7 to 17.8 t ha^{-1}.

Soil pH, EC and GR showed spatial patterns. Omnidirectional semivariogram models were the best fit. A Spherical model best described EC (Fig.5) as follows: nugget = 0.17 (dS $m^{-1})^2$, sill = 0.62 (dS $m^{-1})^2$, range = 31.27 m, r^2=0.94. Similarly GR was described as: nugget = 1.87 (t $ha^{-1})^2$, sill=2.73(t $ha^{-1})^2$, range = 50.78 m, r^2 = 0.80. The soil pH was best described by a linear model as: nugget = 0.05, slope = 0.00015, r^2 = 0.91. Therefore, one uniform rate of gypsum was not a judicious application. A new set of criteria was developed, to divide the farm into well defined management-units.

Variable rates of gypsum thus determined were compared with a single uniform rate for reclamation of the salt affected sodic soil. The field was divided into three management zones (Fig.6), with six transects. One strip in each transect received a uniform rate of 4.25 t ha^{-1} , while the other strip in each zone was treated with varying rates of gypsum i.e. low (3.198 t ha^{-1}), medium (6.77 t ha^{-1}) and high (12.802 t ha^{-1}). The farm was planted with wheat. GR at harvest was significantly lower in the variable-management strategy (1.93 t ha^{-1})

Table - 3: Management zones and fertilizer rates

Management Unit	Fertilizer rate N (kg ha^{-1})	Area Proportion
1.	80	0.18
2.	110	0.39
3.	125	0.43

Table-4: Economics of fertilizer application for uniform-rate and variable-rate fertilizer application

Management strategy	Fertilizer N-P_2O_5-K_2O (kg ha^{-1})	Yield (kg ha^{-1})	Net return (Rs ha^{-1})	Cost:Benefit ratio
Variable	111-90-60	3631	11810	4.35
Uniform	120-90-60	3729	12099	4.29

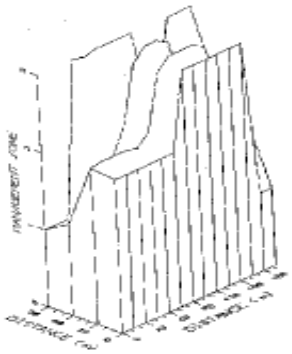

Figure - 4: Map showing Position of Different Management Zones for Variable N Rates

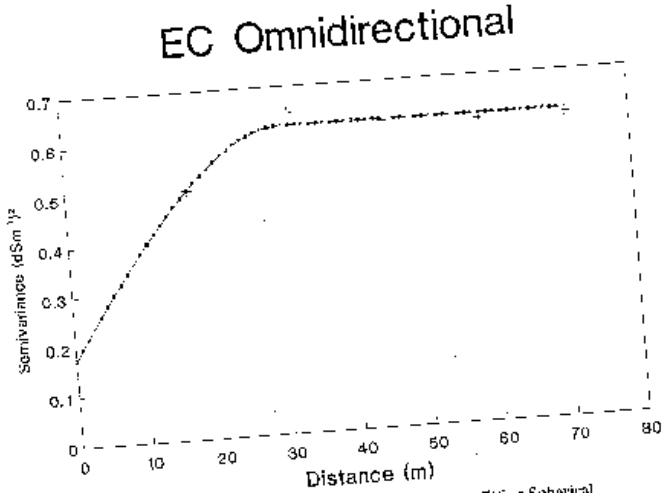

Figure - 5: Plot Showing Semivariance and the best fitting Spherical Model for EC

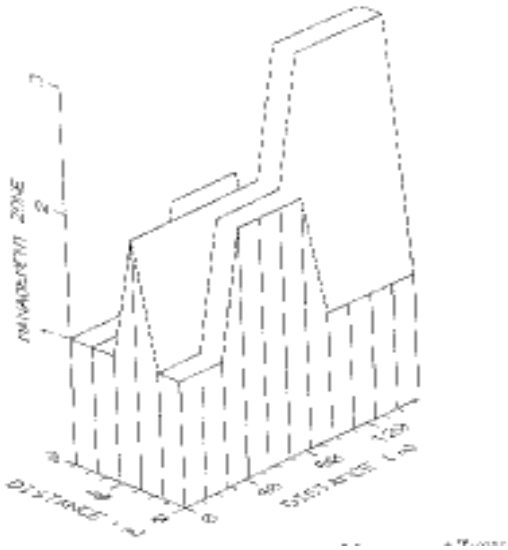

Figure - 6: Map Showing Positions of Different Management-Zones for Variable Gypsum-Rates

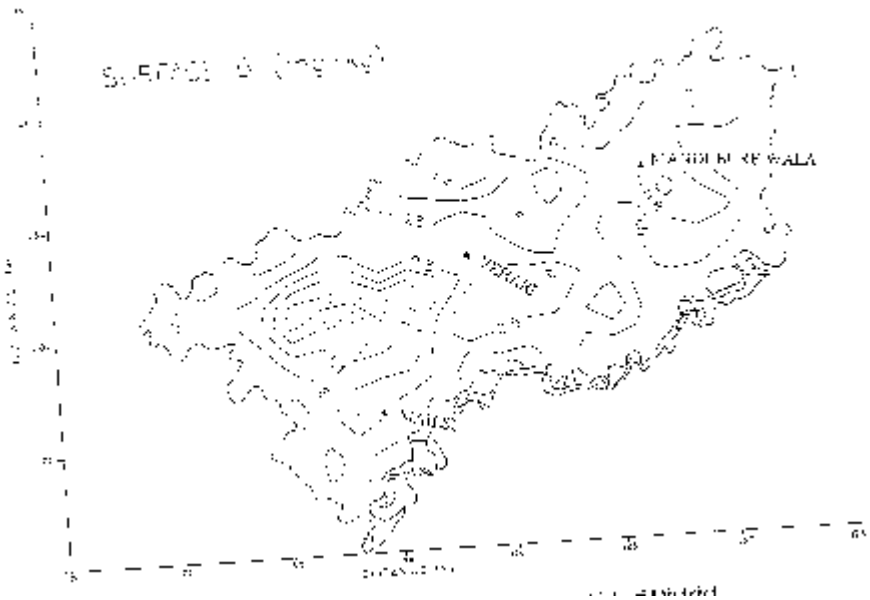

Figure - 7: Map of Soil P (mg kg^{-1}) by Kriging, Vehari District

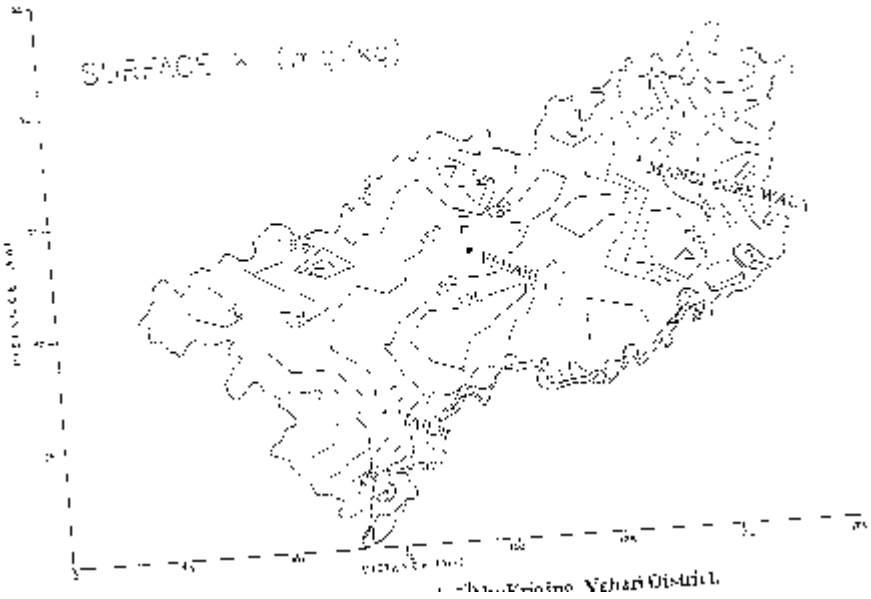

Figure - 8: Map of Soil K (mg kg^{-1}) by Kriging, Vehari District

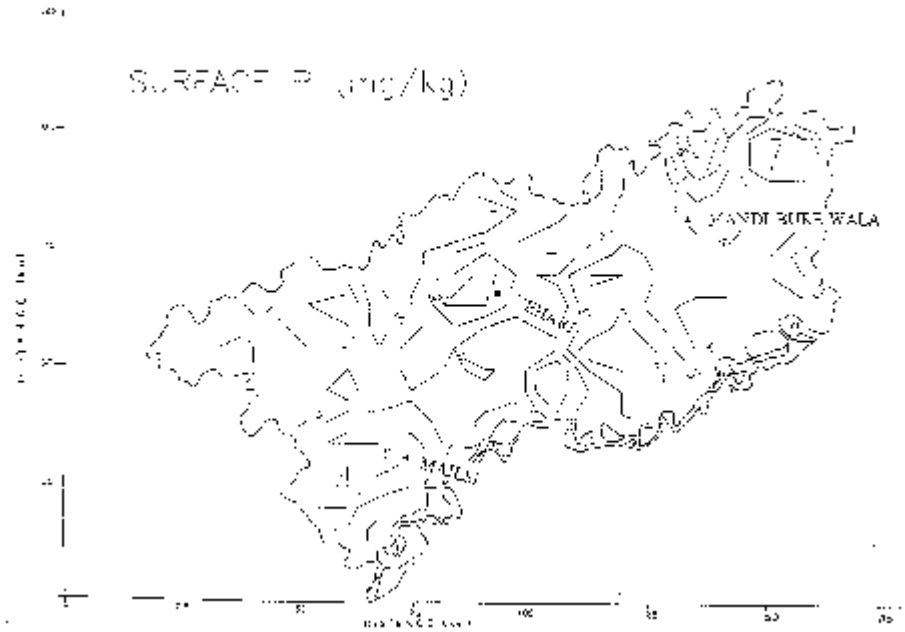

Figure - 9: Map of Soil P (mg kg^{-1}) by Kriging, Vehari District

than in the uniform rate (3.099 t ha^{-1}) (t = -5.2403, P = 0.0000). Wheat-yields were not affected significantly by the two management-strategies. Division of the field into three different management-units, based on the GR of soil, was effective in reclaiming the soil and it increased the efficiency of gypsum application.

3. Mapping of soil fertility

The nutrient contents in soils of cotton-growing areas of districts Lodhran, Khanewal and Multan were subjected to geostatistical technique of semivarogram analysis. Omnidirectional semivarograms were developed for each plant-nutrient, to describe and model the spatial variability. Different semivariogram-models were fitted to these data and parameters for these models were determined.

Values of plant-nutrients under study at unsampled locations were estimated, using the semivariograms and kriging technique. Computer-generated contour maps were developed for delineating areas of nutrient deficiency and adequacy in each district (Fig.7 to 9 for example).

CONCLUSIONS & FUTURE RESEARCH NEEDS

Geostatistical techniques proved to be a suitable tool to identify and describe the spatial patterns of sol-properties and wheat-yield. Use of spatial patterns in soil-properties and wheat-yield identified by geostatistical of semi-variogram analysis helped to divide the field into different management-zones for fertilizer-management, as well as gypsum-application for reclamation of salt-affected soils. Variable rates of N as well as gypsum, thus determined, increased their efficiency. Similarly the use of semi-varogran analysis and Kgriging techniques estimated the values of plant-nutrients at unsampled locations and were used in developing maps of cotton-growing areas of Punjab.

Future Research Needs include:

- Use in soil-survey operation for structural analysis of soil-variation, to help understanding of soil-genesis and for analysis of reconnaissance-data for defining future sampling;
- Kriging, to augment general - purpose information contained in conventional soil-maps, by interpolation of interpretive data and specific measured soil-properties.
- Block kriging, for estimating soil-amendment requirements over areas the size of land-management units.
- Spatial interpretation of critical levels of soil-constraints to crop-production, by using within-field variation of properties, such as soil-moisture content, for improving the efficiency of irrigation water use, nutrient levels for fertilizer application, or soil-chemical properties for amendment needs, such as gypsum requirement;
- Identification of spatially dependent component of error for reducing the confounding effects of within-plot variability on treatment-effects in agricultural experiments;
- Use of spatial dependence in determining optimal plot-size and spacing of samples within plots;
- Mapping of soil-fertility and salinity/sodicity for management of degraded lands.

SOME RESEARCH PRIORITIES

a) Preparation of isarthmic maps of soil-fertility for delineation of deficient areas in major as well as minor plant-nutrients, at field level and at some administrative-unit levels, for proper fertilizer-management to increase efficiency of fertilizer-use and reduce environmental pollution of surface and underground water;

b) Preparation of isarithmic maps of soil-salinity/sodicity for reclamation purposes and to increase the efficiency of amendments;

c) Design of soil-sampling schemes that are less time-consuming and more cost-effective.

d) Design of field experiments, using spatial dependence of soil-properties within plot, to determine the true treatment-effects and making sound conclusions and solid recommendations on fertilizer application.

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EFFECT OF BOVINE SOMATOTROPIN ON THE LACTATIONAL AND REPRODUCTIVE PERFORMANCE OF LACTATING DAIRY COWS - A REVIEW

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ABSTRACT

Bovine somatotropin (bST) increases milk production in dairy animals. The maximum increase in milk production has been observed up to 41%. Somatotropin did not change milk composition significantly. During short-term application of bST, cows mobilized their body-reserves to support the increased milk production. Although DM intake of cows was increased in the long-term applications, however, gross efficiency of production was improved due to larger increase in milk production than DM intake. Somatotropin did not adversely affect the health and reproductive performance of the cows. Repartitioning of nutrients in body-tissue was primarily responsible for the increase in milk-production but defining the exact mechanism by which bST exerted its effect still requires additional research.

Key words: Bovine somatotropin, Milk production, Milk composition, DM = Daily Mineral.

INTRODUCTION

The effects of somatotropin on the performance of lactating animals have been the subject of interest for over 50 years. It was initially demonstrated that injections of crude pituitary extracts increased milk-production in dairy cows. However, limited quantities of native pituitary somatotropin made field-applications impractical. The advent of recombinant DNA technology allowed the production of relatively large quantities of synthetic bST. Since then, a lot of research has been conducted to see the effect of bovine somatotropin on various production-parameters of dairy cows (Peel et al., 1985; Richard et al., 1985; McGuffey et al., 1990). Milk yield had been increased upto 41% with daily injections of bST (Bauman et al., 1989). Cows adjust their voluntary feed-intake to support increased milk-yield (Eppard et al., 1987). Somatotropin did not affect the cows' health and reproductive performance (Eppard et al., 1985a). Coordinated changes in many tissues and physiological processes occurred to support the increases in the synthesis of lactose, fat and protein in the mammary glands. Changes in the irreversible loss and oxidation rates of two key metabolites, glucose and free fatty acids, could quantitatively account for increases in lactose and milk-fat during the support-term administration of bST (McDowell et al., 1987). Similarly, changes in feed-intake accounted for increase in milk-production in the longer experiments (West et al., 1990). The present paper has the objective to review the effect of bST on different lactational and health aspects of dairy cows.

MILK PRODUCTION

Daily administration of exogenous bST derived from the extracts of pituitary glands, or even the growth hormone release factor from the extracts of the hypothalamus (Enright et al., 1988) of slaughtered cows or recombinantly derived bST, cause a higher milk-yield without altering the gross composition. Almost similar results of increased milk-yield in dairy cows by bST administration was reported in many studies (Asimov and Krouze, 1937; Pocius and Herbein, 1986; Richard et al., 1985; Soderholm et al., 1988; West et al., 1990). In a long-term study with Holstein cows, bST treatment increased the average fat-corrected milk (FCM) yield in a dose-dependent fashion from 23 to 41% over control production (27.9 kg/d) in lactating cows (Bauman et al., 1989). However, increasing increments of bST show less increase. In another experiment, 32% increase of milk-yield was reported in cows treated with 100 IU/day of bST over control (Eppard et al., 1985a); they also found a pattern of diminishing marginal response of milk-yield to increasing hormone dose. Similar results have been reported by other workers (Eisenbeisz et al., 1990; Elvinge et al., 1988; Soderholm et al., 1988).

Increase in milk production of cows given bST at their peak lactation was less than for those treated at mid to two third of their lactation (McDowell et al., 1987; Richard et al., 1985). The cows receiving 41.2 mg/d of bST in their early lactation reduced 10% more 3.5%

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FCM than the control group (Schneider et al., 1990). This increase was less than that reported by other workers in the cows treated with bST after their peak lactation (Elvinger et al., 1988; West et al., 1990). This indicated that, even though responses: to exogenous bST did occur, the response was much less than that after peak lactation. One explanation of this was that during early lactation the response might be limited by nutrient availability, because cows were in considerable negative energy balance. The other possible reason for this reduced response was limited supply of glucose for lactose rather than by the ability of cows to mobilize body-reserves in support of lactation (Richard et al., 1985). Administration of bST, either by daily injections or in a sustained release vehicle, had no significant differences in milk or solid-corrected milk of treated cows (McGuffey et al., 1990). In a previous study it was shown that bST administered by prolonged release formation was effective in improving milk-yield and productive efficiency of cows (Bauman et al., 1989).

MILK COMPOSITION

The complex composition and unique biophysical properties of milk can easily be disturbed by slight deviations in composition. Nevertheless, the cow receiving bST seems to have the ability to produce more milk with the same mammary gland, while retaining normal product composition. This has probably much to do with the physical limitations for the composition of milk, as mentioned by Walstra and Jenness (1984). First, milk is iso-osmotic with blood. In milk, lactose, K, Na, and Cl contribute to osmotic pressure. Variations in the lactose content of milk are small, but if they occur, osmolality is maintained by changing K+ directly and Na^+ and Cl^- inversely. Second, the milk is saturated with calcium phosphate and calcium citrate. Additional Ca, phosphate, and citrate are present in the form of a colloidal complex with casein. Third, to be readily digested, the final melting point of the milk-fat must not be higher than body temperature. Crystallization of fats with higher melting points might also occur in cells and alveoli, causing partial coalescence of fat globules in the udder. Therefore, a certain amount of short-chain and unsaturated long-chain fatty acids will be present in milk fat. However, these physiological phenomena do not fully guarantee unchanged milk properties.

Somatotropin did not influence milk-composition of dairy cows. No change in percentage of fat, protein or total solid milk was reported (Eisenbeisz et al., 1990). Fat, protein, and lactose contents of the milk are negligibly affected by bST when the cow is in positive energy-balance. This state is an important prerequisite when bST is administered (Vandenberg, 1991). Similar results had been found in other studies (Elvinger et al., 1988; Peel et al., 1985; West et al., 1990). They noted no change in percentage of milk-fat, protein and total solids with bST treated milk of dairy cows. Contrary to this in some studies, the protein and fat percentage of milk of cows treated with bST were influenced (Eppard et al., 1987). As the dose of bST increased, fat percentage of milk also increased but protein percentage declined in cows with negative energy balance. This can be concluded from various short and long-term experiments (Mcbride et al., 1989; Rohr, 1988; Sainoni et al., 1988). Sechen et al. (1989) found an increased secretion of N and C in milk and decreased urinary loss of N and tissue use of C from bST administration.

Administration of bST in a sustained-release vehicle biweekly or once every week is more practical than more frequent administration. On the average, the milk has fat and protein contents rather similar to those of milk from untreated cows. However, some cyclic effects in fat and protein contents are found. Bovine somatotropin may also cause an increase in the relative amount of long-chain fatty acids, and the somatic cell count was sometimes increased (Vandenberg, 1991).

Experiments show that there was no effect on percentage lactose of milk from bST treated cows (Bauman et al., 1985; Pocius and Herbein, 1986; Bauman et al., 1989; Phipps, 1988; Rijpkema et al., 1989). Lactose percentage decreased significantly at peak lactation but no change was noted at mid lactation in the milk of bST treated cows (McDowell et al., 1987). Changes in milk composition probably reflected the nutritional status of the cows at different metabolic stages of lactation. Protein concentration declined in cows with negative energy-balance, suggesting that protein synthesis by the mammary glands could have been limited by the supply of amino acids.

The information on milk-protein composition, in relation to the bST treatment of the cows, is summarized in Table-1. Caseins are present in milk in the form of micelles, together with Ca, phosphate, and citrate. The cows treated with bST do not seem to produce milk with a different casein-content (Escher and Vandenberg, 1987). The casein:total protein ratio has not changed in most cases, except in three investigations, in which a slight decrease occurs (Table-1). No real differences between the properties of the caseins i.e., the size of the micelles (Vignon and Ramet, 1988) and the various fractions in which calcium is present in milk (Desnouveaux et al., 1988), were observed from the milk of the bST treated and untreated cows.

An increase in the fat content of milk during bST administration is often caused by an extra mobilization of the fat-reserves of the animal, because of an energy shortage. This is most likely to occur just after the start of the treatment. This situation leads to an increase of the longer unsaturated fatty acids in the milk fat and to lower cholesterol and phospholipid contents (Table-2) in the milk (Bitman et al., 1984). Another study showed a slightly increased cholesterol content of the milk fat (Lynch et al., 1989). At very high daily doses of bST and a negative energy-balance, an increase of the proportion of the long-chain unsaturated fatty acids was found by Eppard et al. (1985b). At lower doses and a positive energy balance, the effects on the milk fat were not significant. In general, the fatty acid composition can be affected by the energy state of the cow and a negative balance will more easily occur in high producing cows, in particular, when bST is administered in higher doses and in early lactation.

The cation flux from blood plasma into the mammary gland and into the milk is increased with the milk yield, in order to maintain osmotic regulation; the concentration of the minerals is probably not affected (McBride et al., 1988). This has been confirmed for Ca, P, Na, Fe, Cu, and Mn by many workers (Eppard et al., 1985; Desnouveaux et al. 1988; Auberger et al., 1988; Bauman et al. 1989)

Little research has been conducted into the enzymes in milk, in relation to the administration of bST to the dairy cow. The activities of the aminopeptidase, endopeptidase and phosphatase (Desnouveaux et al., 1988), protease and lipase (Lynch et al., 1988) and lipoprotein lipase (Lough et al., 1989) in milk showed no significant differences between the milk from the treated and untreated groups.

Vitamin A, thiamine, riboflavin, pyridoxine, vitamin B_{12}, biotin, pantothenic acid, and choline have been investigated by Hartnell (1986) and no differences were observed, except for biotin, which was present in a slightly increased concentration in the bST milk.

The pH of the milk was not affected by bST injections in differerent studies (Baer et al., 1989; Battistotti and Bertoni, 1988; Escher and Vandenberg; 1987; Vandenberg and deJong, 1986; Vignon 1988; Vignon and Ramet, 1988).

Differences in Somatic cell count of milk of bST treated and untreated cows were found to be non-significant in most of the studies. However, this topic needs further investigation under various local conditions, because incidence of mastitis and higher SCC sometimes occur in highly producing cows, thus suggesting that special attention be paid to bST-treated cows.

FEED EFFICIENCY, DRY-MATTER INTAKE AND BODY WEIGHT

Dry-matter intake, feed efficiency and body weight were influenced by the bST treatment in dairy cows. The feed intake of cows treated with bST changed after eight week of treatment, and it had increased upto 13.4% by week 22 (Peel et al., 1985; Soderhalm et al., 1988). The voluntary intake of cows receiving bST increased gradually and, by 10th week of treatment, the animals attained positive energy-balance (Bauman et al., 1989). A gradual increase in feed intake of cows treated with bST for a longer period of time was observed (Eisenbeisz et al., 1990; Elvinger et al., 1988; McDowell et al., 1987; West et al., 1990). Cows receiving bST consumed 4 to 10% more feed, but increase in milk production was larger than this and, therefore, it showed that bST treated cows increased the efficiency of production by 11 to 17% over control animals (Soderholam et al., 1988). Increase in gross efficiency of production by bST treatment had also been reported by many other workers (Bauman et al., 1989; Eisenbeisz et al., 1990; Elvinger et al., 1988; West et al., 1990). In all these

Table – 1: Summary of the effect of bST treatment on content and composition of milk proteins, compared with control

Attribute	Result	References
Total protein	Similar	1, 2, 3, 4, 5, 6, 7, 8
	Decreased	9
	Increased	10, 14, 15, 16
Casein content	Similar	1, 2, 3, 10, , 11, 13, 17, 18
	Decreased	9
Relative casein composition	Similar	1, 6, 7, 8
Whey protein content	Similar	1, 3, 6, 7, 8
	Increased	2, 11
	Decreased	9
Relative whey protein composition	Similar	6, 7,12, 13
Casein:total protein ratio	Similar	1, 3, 7, 8, 9,
	Decreased	2, 10,11

[1]Auberger et al.,(1988), [2]Baer et al. (1989), [3]Desnouveaux et al. (1988), [4]Eppard et al. (1988), [5]Sechen et al. (1989), [6]Vignon (1987), [7]Vignon (1988), [8]Vignon and Ramet (1988), [9]Escher and Vandenberg (1987), [10]Barbano et al.(1988), [11]Kindstedt et al. (1988), [12]Lynch et al. (1988), [13]Pabst et al. (1987), [14]Bauman et al. (1989) [15]Phipps (1988), [16]Samuels et al. (1988), [17]Escher and Vandenberg (1988a), [18]Leonard et al. (1988)

Table – 2: Summary of the effect of bST treatment on content and composition of milk-fat compared with those of control cows

Attribute	Result	References
Total fat	Similar	1, 2, 3, 5, 10, 11, 12, 13, 18, 19, 24
	Increased	4,6*, 7, 20, 21, 22
Refractive Index	Similar	7, 23
Properties of:		
Short-chain fatty acids	Similar	6, 14, 24
	Reduced	1,4, 6*, 8
Medium-chain fatty acids	Similar	6,14,17, 24
	Reduced	1, 4, 6*
Long-chain fatty acids	Similar	6, 14, 17, 24
	Increased	1, 6*
Long-chain unsaturated fatty acids	Similar	6, 14, 17
	Increased	1,4,6*,8
Cholesterol	Increased	15
	Reduced	4
Phospholipids	Reduced	4

*At high bST dose and negative energy balance.

[1]Baer et al. (1989), [2]Barbano et al. (1988), [3]Bauman et al. (1989), [4]Bitman et al.(1984), [5]Eppard et al. (1988), [6]Eppard et al. (1985b), [7]Escher and Vandenberg (1988), [8]Farries and Profittlich (1988), [9]Farries (1989), [10]Firkins et al. (1989), [11]Jenny et al. (1989), [12]Lebzien et al. (1989), [13]Leonard et al. (1988), [14]Lynch et al. (1988), [15]Lynch et al. (1989), [16]Oldenbroek et al. (1989), [17]Pell et al. (1988), [18]Rijpkema et al. (1987), [19]Rohr (1988), [20]Rock et al. (1989), [21]Rowe-Bechtel et al. (1988), [22]Sainoni et al. (1988), [23]Vandenberg and deJong, (1986), [24]Vignon, (1987),

studies, although DM intake of cows increased gradually in the long run, but higher increases in milk production led to improved efficiency of production.

Dry-matter intake and digestibility by cows was not affected by bST treatment in short-term studies (Eppard et al., 1985a; Pocius and Herbein, 1986; Schneider et al., 1990). However, these studies also indicated increased efficiency of production in bST treated cows.

Body weight of cows receiving bST was not affected significantly (Elvinger et al., 1988; McGuffey et al., 1990; Peel et al., 1985; West et al., 1990).

HEALTH AND REPRODUCTION

Somatotropin did not adversely affect the health and reproductive performance of cows (Bauman et al., 1989). It was reported that the health and reproductive parameters, including clinical observation, physical examination, somatic cell count, conception rate, services per conception and gestation-length were at or better than resident-herd average (Bauman et al., 1989). Other workers did not observe any adverse effects of bST on the reproductive performance of cows (Eisenbeisz et al., 1990; Elvinger et al., 1988). In a long-term study, it was demonstrated that bST had no discernible effects on mammary health, based on somatic cell count and incidence of clinical mastitis (Eppard et al., 1987). Cows receiving bST showed an average of 96% conception rate, 2.0 services per conception and 116 days open, which were comparable to control-groups. No subclinical or clinical evidence of ketosis or milk fever was observed. Somatropropin treatment had no significant effect on gestation-length or birth weights and growing rate (first 28 days) of calves. Milk yield for the first sixty days, post-partum, was compared for the period just prior to start of treatment and the lactation subsequent to treatment: no treatment effects were observed. Cows were in excellent health during lactation, as was borne out by lactational performance.

MODE OF ACTION

Nutrient Partitioning

Somatotropin increased milk-yield in dairy cows through its coordinated effects on a number of body-tissues and physiological metabolites. A summary of the biological activities of somatotropin has been given in Table-3.

In a long-term study with dairy cows, a homeorhetic control (the coordination of changes in metabolism necessary to support a given physiological state e.g., pregnancy, lactation) involved in the orchestration of 'partitioning of nutrients' to support the requirements for milk synthesis was considered (Bauman et al., 1989). The term 'nutrient partitioning' is most commonly used to describe the manner in which absorbed nutrients are directed to various tissues and organs in support of productive functions. In a more general sense, the definition should also take into account other partitioning, such as between digested versus undigested nutrients or between production functions versus the overhead costs of maintaining the animal. Because these may also be affected by bST, they must all be considered as components of the nutrient partitioning process.

The results of 'nutrient partitioning' in long-term studies were based on the fact that increased milk yield could not persist through the treatment-period unless coordinated changes occurred in body-metabolism, so that steady-state conditions were maintained. These changes must have involved the metabolism of lipid, carbohydrates and amino acids, because milk-composition was not altered during the treatments. Other studies using bST demonstrated that milk-composition was unaltered when cows were in positive energy balance (Elvinger et al., 1988; Peel et al., 1985; Soderholam et al., 1988).

Diabetogenic and Lipolytic Effects of bST

The diabetogenic and lipolytic effects of bST have been reviewed by Bauman et al., 1989, and Johnsson and Hart, 1986. In some trials bST treatment of animals elevates circulating concentrations of NEFA, insulin, and glucose (Johnsson and Hart, 1986) and, in others, it does not (Bauman and McCutcheon, 1986), except where treatment drives animals into a negative energy balance, in which case NEFA are chronically elevated. This may relate to the capacity of treated cows for milk production. Treatment of low-yielding beef cows with bST elevates circulating glucose, but high-yielding dairy cows did not respond in the same manner (Bines et al., 1980). It was suggested that bST treatment

Table – 3: A summary of the biological activities of somatotropin[1]

	Biological activity	Brief details
1.	*Cell division*	
	Promotion	Numbers of cells in muscle, liver, spleen, mammary, and other tissues, DNA polymerase.
2.	*Protein metabolism*	
	Promotion	Nitrogen retention; uptake of amino acids and incorporation into protein; RNA polymerase, elongation of mRNA; polyamine synthesis.
3.	*Carbohydrate metabolism*	
	Promotion	Tissue glycogen deposition; pancreatic release of insulin; peripheral insulin resistance; plasma glucose concentrations.
4.	*Lipid metabolism*	
	Promotion	Fatty acid release from adipose tissue; oxidation of fatty acids.
	Inhibition	Fat synthesis; adipocyte enlargement.
5.	*Mineral metabolism*	
	Promotion	Deposition of calcium and phosphorus in bone; calcium turnover; retention of sodium, potassium, and phosphorus.

[1]Machslin (1976).

increased the availability of glucose in each group, but it was completely utilized for additional milk secretion by high-yielding cows only (Johnsson and Hart, 1986). It is therefore hypothesized that the diabetogenic and lipolytic effects have not been seen in high-yielding cows, because of the increased drain on circulating nutrients caused by high milk secretion-rates. Some other studies do not agree with this hypothesis, like the experiment of Brumby and Hancock (1955), in which no effects on blood glucose were observed, in cows treated with pituitary-derived bST. However, substantial (up to 45%) responses in milk-yield were observed following bST treatment. These observations lead to two conclusions. First, the absence of altered blood-metabolite concentrations in some bST studies (Bauman and McCutcheon, 1986) is not simply a function of greater mammary nutrient-drain in high-producing cows. Second, and more important, significant lactational responses to bST do occur, in both high and low producing cows, in the absence of 'lipolytic' and 'diabetogenic' changes. It follows that these changes are not an intrinsic component of the mechanisms by which bST promotes increased lactational performance. Marked metabolic changes must be occurring to permit substantial lactational responses to bST while, at the same time, allowing treated animals to maintain their homeostatic balance, as measured by circulating metabolite concentrations.

Effect Of bST on Carbohydrate Metabolism

Treatment of lactating cows with bST induces marked increases in milk-yield and, since lactose content of the milk is not altered, this requires a substantial increase in supply of glucose to the mammary gland. DeBoer and Kennelly (1989) reported that treatment with bST injection had no effect on glucagon, insulin or glucose metabolism. They had, therefore, concluded that factors other than bST might play a role in production. Nevertheless, the changes in glucagon, insulin and glucose metabolism were consistent with the concept of homeorhetic actions of bST.

The increased supply of glucose to the mammary gland can be achieved in a number of ways. First, bST inhibits the uptake of glucose by peripheral tissues (e.g., adipose) and reduces whole-body glucose oxidation to CO_2 (Baman et al., 1988). The overall effect of these changes is that utilization of glucose by peripheral tissues is greatly reduced, thus sparing glucose for lactose synthesis. Second, bST treatment appears to increase gluconeogenic rates, thereby directly increasing the supply of glucose via de novo synthesis (Bauman et al., 1988). The extent to which these mechanisms contribute to the increased supply of glucose for lactose synthesis undoubtedly varies according to the animal's particular circumstances.

Effect Of bST on Amino-Acid Metabolism

Oxidation of amino acids decreased with bST treatment, as it caused a concomitant increase in oxidation of NEFA in growing heifers. The net effect is an increase in whole body protein-synthesis and a decrease in lipid accretion, consistent with the production-effects of exogenous bST in growing animals (Boyd and Bouman, 1989). Increase in milk-protein secretion by a short-term bST treatment occurs due to reduction in oxidation of amino acids and increased mobilization of labile protein reserves, whereas in long-term studies increase in voluntary feed intake also contributes towards more milk-protein secretion.

Effect of bST on Lipid Metabolism

The principal effect of bST is to partition nutrients in such a way that lipid accretion is reduced and fatty acids made available for oxidation. This has the effect of 'sparing' nutrients, such as glucose and amino acids, and is achieved by reciprocal effects on lipo-genesis and lipolysis. The bST treatment caused an increase in plasma free-fatty-acids (FFA) concentrations, without altering blood ketone, suggesting that lipolysis was increased without corresponding increase in fatty acids oxidation by the liver (Pocius and Herbein, 1986). They had opined that bST acted by partitioning FFAs towards milk production. It was also reported that there was an increase in plasma FFA in the blood of bST treated animals (Lough et al., 1989). However, they did not find any difference in lipoprotein lipase-activity in milk, mammary tissues and acetate metabolism in cows injected with bST. It raised the possibility that higher serum triglyceride concentrations induced by bST might have increased the availability of preformed lipids to the mammary glands for increased rate of milk-synthesis without an increased mammary lipase activity. It was also demonstrated that bST exerted its metabolic effects, resulting in the provision of substrate to the mammary gland for milk biosynthesis (McDowell et al., 1987). They further noticed that bST exerted different metabolic effects, depending on the physiological state of the animal. They, thus, concluded that bST exerted a homeorhetic control, resulting in the provision of nutrients to the mammary gland at the expense of the body-tissues for milk synthesis. Similar hypothesis had been extended by another worker (Soderholm et al.,1988).

One of the most obvious in-vivo responses to bST is increased sensitivity to lipolytic stimuli. Thus, circulating NEFA following an acute intravenous epinephrine challenge are elevated in bST-treated dairy cows and growing cattle. These changes occur, whether or not the treated animals are in positive or negative energy balance (i.e., whether or not basal circulating NEFA are altered). The enhanced lipolytic sensitivity of treated cows was also co-ordinated with their increased fat yields (McCutcheon and Bauman, 1986). Although bST enhances the antilipolytic effects of insulin, it appears to antagonize the ability of insulin to stimulate lipogenesis. Treatment with bST appears to reduce the activity of several key lipogenic enzymes in vitro (Schaffer, 1985; Magri et al., 1987; Vernon et al., 1988) and to inhibit the transport of glucose into adipocytes. The latter effect was not mimicked by insulin-like growth factor (IGF)-I or IGF-II treatment, suggesting that it was a direct effect of bST (Schoenle et al., 1985). As a consequence of these reciprocal effects on lipolysis and lipogenesis, bST partitions nutrients in such a way that lipid accretion is reduced or lipid reserves mobilized. Thus, in lactating animals, the size of lipid reserves tends to decline (particularly during the early phases of treatment) but in growing animals, rate of lipid deposition is reduced in adipose tissue (Bauman and McCutcheon, 1986; Boyd and Bouman, 1989). Moreover, the rates of NEFA oxidation to CO_2 are increased (Dunshea et al., 1989; Tyrrell et al., 1988) so that NEFA make a proportionately greater contribution to the animal's energy requirements. This in turn means that glucose and amino acids, which might otherwise be oxidized to provide energy, are available for milk lactose and protein-secretion or for tissue protein deposition.

Effect of bST on Voluntary Feed Intake

Bovine somatotropin increased the voluntary intake of cows after several weeks of treatments (Eisenbeisz et al., 1990; Politis et al., 1990). This observation raised another possibility for mechanism of action for bST in the long-term treatment. This observation supported the simple contention that an animal ate to maintain energy homeostasis, so that daily energy intake matched daily energy output. In the earlier weeks of treatments, body tissues were mobilized to

subsidize the increased demands of the mammary glands and the substantial increase in milk energy output. Voluntary feed-intake then increased to meet the additional demands of the mammary gland and the rate of live weight-loss was first stabilized and then reversed.

Effect Of bST on Mammary Gland Tissues

There was no evidence to indicate that bST has a direct effect on mammary gland tissues during established lactation. Direct infusion of bST into mammary artery did not affect rate of milk-synthesis (Peel et al., 1985). It was also demonstrated that bST did not bind to the receptors in bovine mammary tissue (Gertler et al., 1984). It was probable that bST affected mammary gland mechanism indirectly via stimulation of the synthesis of somatomedins or other protein-factors by the liver. These factors might then act directly on mammary gland. Chronic bST administration had been shown to stimulate a significant elevation of somatomedin concentrations by 22nd week of treatment (Peel et al., 1985).

The somatotropin treatment increased the blood flow to the mammary glands of the ruminant animals. The relationship between mammary blood-flow and milk-yield approximates 500:1 under normal conditions (Linzell, 1974). In lactating ewes (McDowell et al., 1988), the ratio was increased from ca. 460:1 before to ca. 505:1 during administration of pbST. Studies with dairy cows indicated an increase in the ratio from ca. 520:1 to ca. 580:1 during administration of pbST (McDowell et al., 1987). Estimates were made 3 to 5 days after commencing daily injections of pbST and it was assumed that the mass of mammary tissue was not affected by the pbST.

The increase in blood flow to the mammary gland appears to be partially attributable to an increase in cardiac output (Davis et al., 1988a), as had been suggested by Mepham et al. (1984). Davis et al. (1988b) expressed the view that it would be unlikely that the increase in mammary blood-flow occurring during treatment with bST would be the cause of increased milk production. Instead, increased blood flow would likely be the result of altered metabolic activity of the mammary glands, as indicated by a measured rise in oxygen-consumption by the glands of cows injected with pbST. Another possible cause of increased blood-flow during administration of bST may be IGF-I. Glim et al. (1988), by using the immunofluorescent techniques, reported that IGF-I was present in small blood vessels, including the capillaries, located within the stroma of the mammary gland, before and after commencement of daily injections of bST. They further reported that increase in plasma IGF-I occurred in response to exogenous bST, which could explain the increased blood flow to tissues, including the mammary gland. The increased flow of blood to the mammary glands would result in the supply of additional nutrients, thereby facilitating increased milk synthesis.

Latest model for mechanism of action for bST on mammary gland was reported that in bST injected cows, milk plasmin was maintained at low concentration, and milking performance was enhanced (Politis et al., 1990, Sarwer et al., 1995). Cessation of bST injection at drying-off led to a rapid elevation of milk plasmin to control values. They had, therefore, hypothesized that bST suppressed plasmin production involution and allowing the persistence of milk production.

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PHYSICAL SCIENCES AND TECHNOLOGY

LONG-TIME AGING CHARACTERISTICS OF Al-MG-Si COMMERCAIL ALLOY

*S. Khan, M. Farooque, A. Ul Haq and A.Q. Khan**

ABSTRACT

The influence of long-time aging on hardening precipitates of Al-Mg-Si commercial alloy has been investigated. Samples were heat treated at different aging temperatures ranging from 120 to 200°C. Incase of prolonged aging (from 0.5-200 hours) the hardness vs aging time curve revealed two peaks, a primary peak and a secondary peak during the aging phenomena. An activation energy of 1.37eV was measured in temperature range of 140-180°C in the present study. Transmission electron microscopy study has identified a low density of fine precipitates during the early stage of aging. However, upon prolonged aging, the precipitation hardening process is associated with high density of Mg_2Si precipitates.

INTRODUCTION

Al-Mg-Si alloys are pseudo-binary alloys. These are known to be age-hardenable and studies have been undertaken to understand their aging behavior[1-8]. The combination of properties, such as tensile strength, ductility, formability, weld ability, together with a high corrosion resistance, and an attractive surface appearance render the Al-Mg-Si system very useful for extruded product[9]. These alloys can be safely used at relatively low temperature, but they start loosing their strength when exposed to the high temperature (above 200°C), primarily due to the coarsening of the hardening precipitates[2]. The influence of heat-treatment on the structure of the Mg_2Si precipitates was first studied by Thomas[10]. He discovered that the precipitates have needle-shaped morphology that continuously changes according to the aging conditions. The sequence of precipitates formation is as follows:

Supersaturated Solid solution → Coherent GP zone of needle shape β′ →

Semi-coherent β″ rods → Incoherent β Mg_2Si plates

The formation of GP zone, β′ and β″ precipitates give rise to an appreciable change in the hardness and other properties of the Al-Mg-Si alloys. It is argued that age-hardening in the Al-Mg-Si alloy is controlled by the migration of mobile Mg-Si vacancy cluster, and the activation energy of the process varies from initial to final stage of aging. The activation energy is affected by the concentration of quenched-in vacancies contained in Mg-Si cluster [6-7].

In this paper we report the effect of long-time aging behavior in Al-Mg-Si alloy as a function of time and temperature. Its effect on hardness and microstructure has also been studied.

MATERIALS AND EXPERIMENTAL

The commercial Al-Mg-Si alloy samples 10 x10 x 1mm in size, having 0.54wt%Mg and 0.34wt%Si, were prepared from a long extruded tube, after sectioning. The samples were homogenized at 420°C for 1 hour and were solution-annealed at 547°C for 1 hour followed by rapid quenching in brine, as it exhibits better cooling rate characteristics[11]. The quenched samples were then aged for a pre-determined time and temperature, in the range from 0.5-200 hours and 120-200°C, respectively.

Hardnesses of the aged samples were measured on polished surface, using a Vickers′s hardness tester at a load of 5kg. To minimize the factor of error, each reported hardness-value is the average of five readings. TEM samples were prepared by mechanical grinding of 3mm diameter disc from a thickness of 1 to 0.15mm. The samples were then electrolytically polished in Fischione twin-jet electro-polisher, using an electrolyte of 10% percholoric acid in methanol at a temperature of -15°C. Thin foils were studied under JEOL-200CX transmission electron microscope (TEM) at an operating voltage of 160 keV.

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1 shows the isothermal linear-log plot of Vicker′s hardness versus aging-time. Initially, the aging was planned at temperatures of 140°C, 160°C and 180°C.

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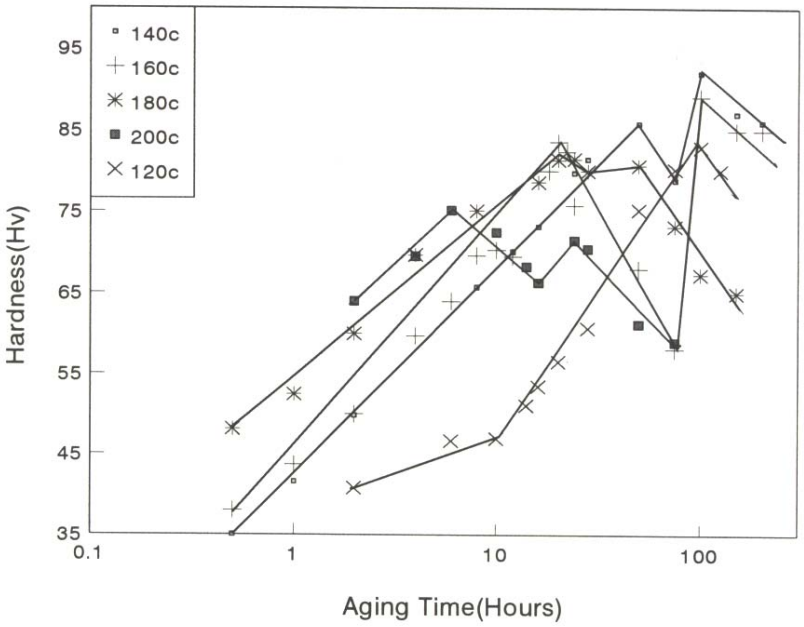

Figure - 1: Hardness (Hv) as function of log aging time (Hours) shows the appearance of primary and secondary peaks.

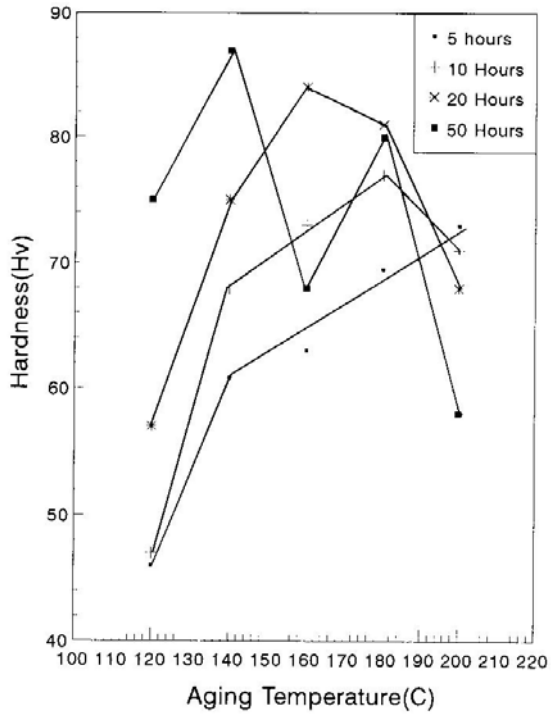

Figure - 2: Hardness (Hv) as function of aging temperature (°C) for fixed time.

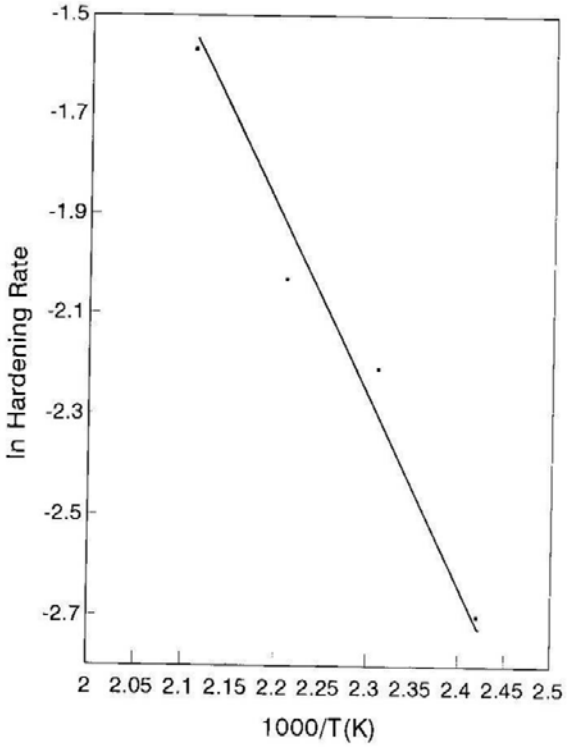

Figure - 3: Arrhenius type of plot of log hardening rte as a function of absolute aging temperature.

The plots show that there is a linear increase in hardness during the early stage of the aging process. After this stage, the hardness drops sharply and then rises again when the alloy is aged further for a longer time. This means, each curve has two hardness peaks, a primary and a secondary peak. The aging curve at 140°C shows the formation of the primary peak around 50 hours, after which the hardness drops and then rises sharply above 100 hours and the secondary peak develops. Similarly, the aging curve at 160°C shows the primary peak around 20 hours of aging and the secondary peak above 100 hours, in analogy to the aging curve at 140°C. Although the difference of time between the two curves to achieve the primary peak is very large, there is only a slight difference in the hardness values. This indicates that growth-rate of precipitate is slower in case of lower temperature.

The sample aged at a temperature of 180°C shows the primary peak after 15 hours, the hardness then slightly decreases and then secondary peak develops above 50 hours. The drop in hardness after the primary peak is not very significant at a temperature of 180°C; however, it follows a trend similar to that at 140°C and 160°C aging temperatures. At higher aging temperature, it takes a shorter time to complete the whole process, as such, primary and secondary peaks for hardness are not developed properly. Following these observations the aging process was repeated at of 120°C and 200°C. The aging phenomena at a temperature of 120°C occurred with two different slopes. The rise in hardness in the first 10 hours is very slow, after which it rises in a normal way as is observed for 140°C, 160°C and 180°C. This further indicates that high activation energy is required for precipitation at low temperatures. In this case, the primary peak was observed after 100 hours of aging. The sample was stopped from further aging after the appearance of primary peak at 120°C, as it was expected to depict a trend similar to that at 140°C, 160°C and 180°C aging temperatures. The aging temperature of 200°C did show the primary and secondary peaks; however, the results at this temperature are not reproducible. Probably reaction kinetics is so high that it is difficult to follow the aging mechanism. Thus it may be concluded that the higher the aging temperature, the lower is the time at which primary and secondary peaks for hardness appears. Furthermore, this aging at 200°C or above is not recommended for these alloys.

Figure 2 shows the plot of Vicker's hardness as a function of aging temperature for fixed time-intervals. Better hardening tendency is shown in the temperature range of 160-180°C and in 10-20 hours after that, the hardness decreases continuously as the aging temperature increases.

The kinetics of age-hardening has been analyzed by employing Arrhenius type of equation of the form:

$$H = H_0 e^{-Q/RT}$$

where H is the hardening rate, H_0 is the structural constant, Q is the activation energy, R is the gas constant and T is the absolute temperature.

Figure 3 is the Arrhenius plot of log hardening-rate as a function of the reciprocal of the absolute aging temperature. The slope of the straight line in figure 3 gives an activation energy of 1.37eV. The aging phenomenon observed in the initial stage of aging in the present study is in agreement with the results of Ismail and Bouchra[7] reported for a similar alloy (Al-Mg-Si). They measured activation energy of 0.95 eV for their alloy, which appears to have better hardening tendency and as a result took shorter time to achieve the maximum peak hardness. Moreover, their peak hardness values are relatively high, which is perhaps the effect of compositional difference of the alloy used in the two studies (0.98wt%Si, 0.78wt%Mg, 0.31wt%Mn and 0.06wt%Fe[7]). However, Ismail and Bouchra have proposed that the low activation energy is probably due to the formation of complexes between quenched-in vacancies and solute atoms. Yanagwa and co-workers have proposed that activation energy for the aging process varies from 0.7-1.1eV for the early stage of aging to 1.3-1.5eV for the later stage. The activation energy is dependent upon the concentration of alloying elements, such as Si and Mg which is a source of precipitates. The value of 1.37eV recorded in the present study is consistent with the result of Ismail and Bouchra and Yanagawa *et al*. It is to be noted that activation energy of 1.43eV and 1.13 eV has also been reported by Hunsikker[14] for diffusion of Si and Mg in aluminum, respectively.

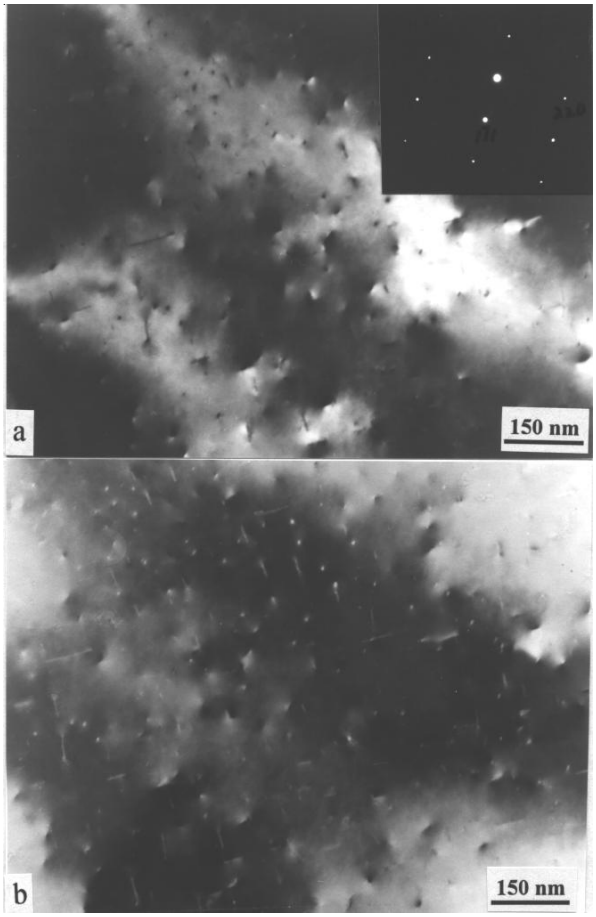

Figure - 4: TEM micrographs show the features of Mg_2Si hardening precipitates in the initial stage of aging process (primary peak) at 160°C after 20 hours. a. Bright Field, b. Dark Field. Diffraction pattern (Zone = [112]) is placed over the micrograph

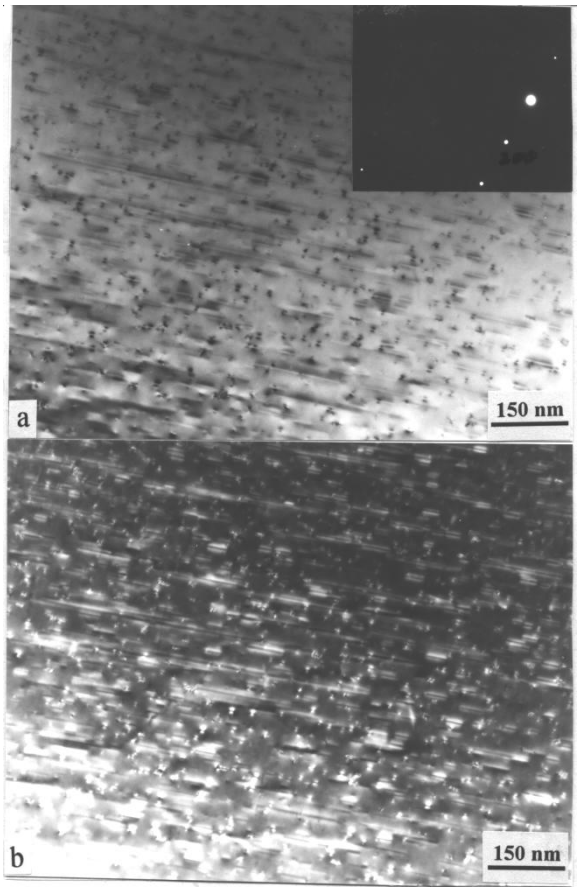

Figure - 5: TEM micrographs show the features of Mg_2Si hardening precipitates at the final stage of aging (secondary peak) at 160°C after 100 hours. a. Bright Field, b. Dark Field. Diffraction Pattern (Zone = [012]) is placed over the micrograph

It is to be noted that, during the whole aging process discussed above, the hardness has higher values incase of secondary peaks as compared to that of the primary peaks (figure 1). The reason for this effect is supported by TEM observation in figure 4 and 5. Figure 4 reveals the feature of needle-shaped β′ hardening precipitates at the initial stage of aging. These are related to the primary peak in figure 1. As the aging of the Al-Mg-Si alloy is continuous over longer times, a high density of rod shaped β′′ precipitates have appeared, which are dispersed throughout the matrix and the curve approaches to the secondary peak. This is evident in the TEM micrograph, figure 5. The change in the type of Mg_2Si precipitates and increase in their density may be the possible reasons for the rise of hardness at the secondary peak. This type of precipitate β′′ was also reported earlier[12-13]. The two peaks (primary and secondary) determined during the aging process are in agreement with the observation reported by Takeda and co-workers[8]. According to them, the peak formed in the later stage of aging is independent of the first peak. This is probably due to the change in the precipitation morphology, as it is observed in the present study. Moreover it was suggested that needle-like Mg_2Si precipitates play a leading role in the aging process. Contrary to this, it is noticed that β′′ rods are dominant; however, these β′′ rods precipitates have formed after 100 hours of aging. This contradiction may perhaps be attributed to the different chemical composition of the alloy used in this study. The variation in alloy-concentration may be responsible for variation in the aging time interval and in the morphology of the hardening precipitates.

It is established[1] that the precipitation-process in the supersaturated solid-solution can take place in two distinct stages, which may be termed as pre-precipitation and precipitation stages. Pre-precipitation stage is characterized by clustering or segregation of solute atoms in the matrix, known as GP zones. The initial stage of aging (primary peak) can be characterized as pre-precipitation stage, where the clustering of the solute atom is more frequent and the growth of the precipitate is less, as is evident in figure 4. In this context, it will be worth explaining that the shape of the precipitate particles and the nature of the interface, between the precipitate and the matrix are of interest, as these have a great influence on the mechanical properties of the resulting two-phase structure. The interface between the precipitate particles and the matrix can only be fully coherent when it is smaller in area and any misfit must then be accommodated by the elastic strain. If the interface becomes large in area, the strain-energy can be reduced by introduction of structural dislocation lying in the interface. Such an interface is not fully coherent[15]. Similar conditions have been discussed [16-17] for an initially coherent precipitate to become non-coherent, as it grows. It is proposed that an initially coherent precipitate will become non-coherent when it is so large that the elastic energy due to the difference in atomic volume of matrix and the precipitates becomes greater than that of the surface energy.

The same situation of non-coherency might have existed during the growth of the Mg_2Si precipitates, which has led to the drop in hardness after achieving the primary peak, figure 1, in Al-Mg-Si alloy. As the aging continues, the growing precipitate changes its type (morphology) from β′ needle to β′′ rods, which ultimately appear as a secondary peak with a higher hardness value in the aging process.

CONCLUSION

In this work, Al-0.54%Mg-0.34%Si alloy was studied under a wide range of aging parameters and the following conclusions have been drawn:

1. The alloy under discussion has less hardening tendency and the desired properties are only obtained if it is aged at 160-180°C for 10-20 hours

2. The alloy, during long-time aging, exhibits primary and secondary hardening peaks.

3. In the initial stage of aging, the growth of the Mg_2Si hardening precipitates was very slow; however, as the aging continues, a high density of Mg_2Si, β′′ rods appeared. An activation energy Q = 1.37eV measured for the initial stage of aging is consistent with the aging-process reported in the literature.

4. The drop in hardness after achieving the primary peak is probably due to the interface structural misfit (non-coherence) between the precipitate particle and the matrix as it grows.

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A DECENTRALIZED PROCESS-ORIENTED APPROACH FOR POWER-SYSTEM OPERATION

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ABSTRACT

It has been pointed out that the problem of "Economic Operation of Electrical Power Systems" is a problem of decision-management. To be able to reach the right decision, the right information is to be made available at the right place, and at the right time. [1J To that end, it is required that the individual tasks involved in electrical power systems, such as economic dispatch, unit commitment, hydro-thermal coordination, etc., be reengineered into decentralized coherent processes.

Keywords: Power Systems and New Developments, Power System Planning & Control, Decentralization of Processes in a Power System

INTRODUCTION

"The operation-scheduling problem is to determine which generating units should be committed r. and be available for generation, the 'units' nominal generation or dispatch and, in some cases, even the type of fuel to use. In general utilities may have several sources of power such as thermal plant (steam and gas), hydro and pumped storage plants, dispersed generation (such as wind-power or photo-voltaic), interconnection with other national or international generation companies. Also many utilities use load management-control to influence the loading factor, thus affecting the amount of generation required. The economic effect of operations scheduling is very important, when fuel is a major component of the cost.

In the present state *of* the art, load dispatch is determined through control program stored in the memory *of* the control center computers. The inputs *to* this program are in the *form of* proprietary data-files, comprising the fuel-cost characteristics *of* thermal units, total system forecast, capability *of* generation resources, etc. This program computes the unit commitment order, as well as dispatch *for* individual units, and the results derived by the center computers are dispatched over the SCADA lines *to* the operators who can then accept, modify or ignore the advice received [5].

It is a centralized decision-management system, which may be simpler to handle if the units to be controlled are small in number and the distances involved are not very large. It is important to note that *some components of the system, that are vital for better decision management are either not linked at all or are linked through slow paper links.*

In order to have an appreciation of the complexity involved, consider the unit commitment problem with following assumptions:

- There are M periods per day.
- There are N units to commit and dispatch
- Anyone of the units, as well as all the units can supply the whole load.

The number of combinations to be tried each hour would be

$$C(N,l) + C(N,2) + \ldots\ldots\ldots\ C(N,N) = 2^N - 1$$

Where $C(N;j)$ is the combination *ofN* items taken *j* at a time

$$C(N,j) = \frac{N!}{(N-j)!j!}$$

which can become a horrid number to think about.. Considering M equal to 24 one hour intervals and a system with N equal to 20 units, this number amounts to 3.12 x 10144. [3] These very large numbers are the upper bounds for the number of enumerations required. What would happen in systems where number of units is more, than 150?

The present advances in the *Information Technology* have enough potential to provide solutions for optimal operation of electrical power systems, with the following benefits:

- Information can appear simultaneously in as many places as it is needed.
- Systems can simultaneously reap the benefits of centralization and decentralization.

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- Decision-making may become part of everyone's job.
- Plans get revised instantaneously.
- A generalist can do the work of an expert.

The overhead on the main center computers can be reduced very much, by reengineering the processes in a logical way. *As an essential enabler, the modern information-technology has an importance to the reengineering process that is difficult to overstate. To reengineer is to take a journey from the familiar into the unknown.* [9*]*

REENGINEERING:

Reengineering as defined by Hammer and Champy [9], is the *fundamental* rethinking and *radical* redesign of *processes,* to achieve *dramatic* improvements in critical contemporary measures of performance, such as cost, quality, service and speed.

"Processes in a company correspond to natural business activity, but they are often fragmented and obscured by the organizational structures. Processes are invisible and unnamed because people think about the individual departments, not about the processes with which all of them are involved. Processes also tend to be unmanaged, because people are put in charge of the departments or work units, but no one is given the responsibility for getting the whole job — the process —done". [9]

PROCESSES AND PROCESS-MAPS

Just like organization charts, a process map can be prepared that gives, a picture of *how workflows* through the organization. [9] Some very interesting characteristics of a process map may be outlined as follows:

- Simple: A process-map is much simpler, as compared to an organization chart of the same company. Hardly any company contains more than ten or so principal processes.
- Process Owners: A process-map includes process owners; something that is almost never displayed on a company's organization chart.
- End Users: A process-map also includes end-users in its view of processes.
- Sub Processes: A process is not seen as a monolith, but in terms of key-concepts to interact with others. This perspective indicates how a system appreciates it's owners work and how it can contribute to that work
- "Process-maps don't require months of work to construct; several weeks is the norm. But this task does induce headaches, because it requires people to think across organizational grain. It's not a picture of the organization, which is what people are used to seeing and drawing, but a depiction of the work that is being done. When it's finished, the process map should not surprise anyone. In fact, people may wonder why drawing it took as long as it did, since the finished map will be so easy to understand, even obvious. Of course, people should say, that it is just a model of what we do around here." [9]

REDESIGNING PROCESSES

Once a process has been selected and a process owner and user defined, the next step is to understand the process. The following are the key issues:

- What the process does?
- How well (or poorly) it performs?
- Critical issues that govern its performance.

Traditional process-analysis takes the process-inputs and outputs as given, and looks purely inside the process to measure and examine what goes on. In contrast to that, part of redesigning a process is, to look at it from the outside in order to find what the process's customer (the user) does with that output. Therefore, the better place to begin to understand a process is on the user-end. The following questions must be answered:

- Who is the user of this process?
- What are the user's real requirements?
- What do they (users) say they want, and what do they really need, if the two are different?
- What problems they have?
- What processes do they perform with the output?

Since the eventual goal of redesigning a process is to create one that meets user's needs better, it is crucial

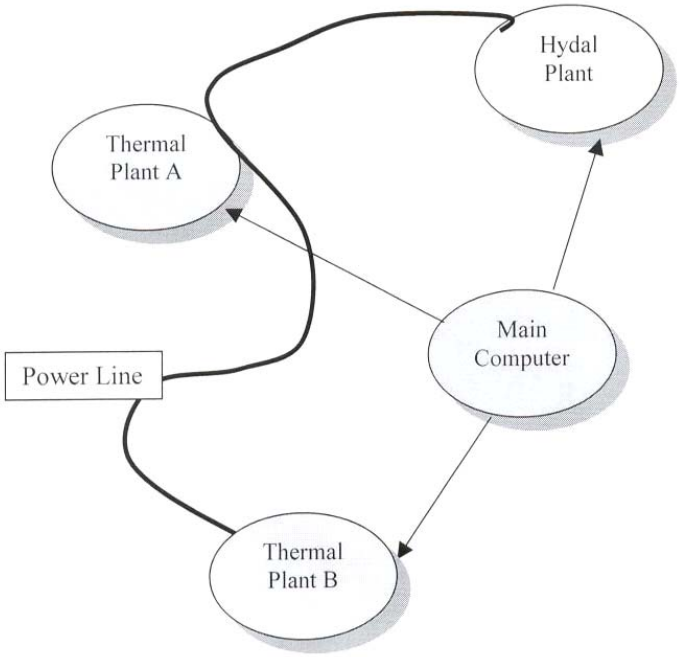

Figure - 1: Control-System Based on Centralized Management for Electrical Power Systems Operations

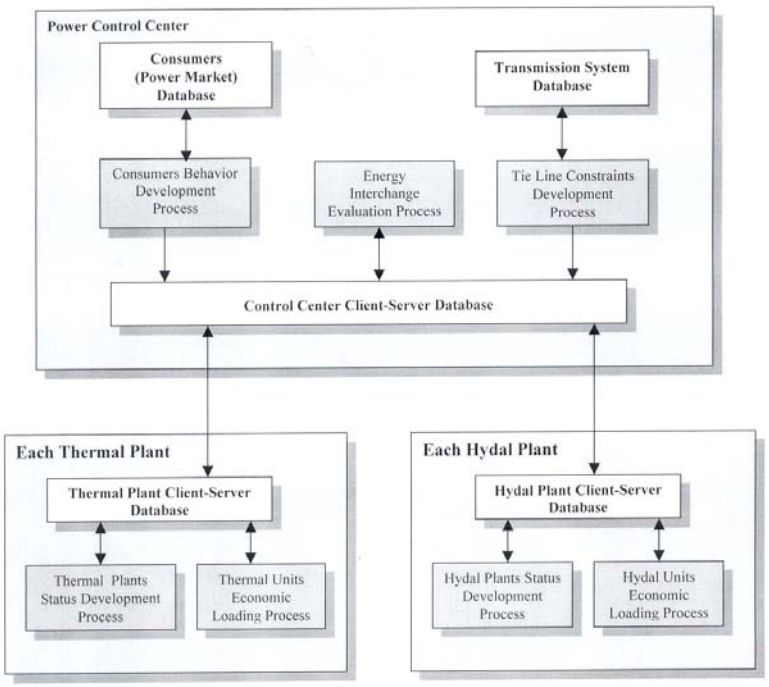

Figure - 2: A Possible Higher-Level Process-Map of an Electrical Power System

that the team truly understands these needs. Understanding means considering the user's underlying goals and problems, not just the mechanics of the process that links the two organizations together.

A PROCESS-MAP FOR POWER SYSTEM OPERATION

According to Hammer and Champy [9], one way to identify processes that make up an organization is to give them names that express their *beginning* and *end* states. This implies all the work that gets done between their start and finish. Some processes involved in operation of electrical power systems, are redesigned in the following, with a view to understanding their inputs and outputs.

THERMAL PLANTS STATUS DEVELOPMENT PROCESS

This process would take in the fuel consumption data, scheduled and forced outages, startup and shut-down information, and would identify the units available and their fuel-cost characteristics, as well as minimum and maximum plant-capability, for next 24 hours. The process-owner is each thermal plant. The customer of this process is the main control center.

ENERGY-INTERCHANGE EVALUATION & PLANT-SCHEDULING PROCESS

This process uses the output of hydel status development process and thermal status development process as its input, along with load-forecast at each load-center for next 24 hours, tie-line constraints, and identifies the units to be committed and optimal share of load for each plant. The process owner is the power-control centre. The customers of this process are each power-plant. This is a shared process, which requires a few hops between plants and main control-centre, for its completion.

PLANT UNITS ECONOMIC LOADING PROCESS:

This process would utilize the output of the above process and produce optimal share of load for each of its ONLINE units. The process owner is each thermal plant. The owner of this process is also the customer of the process. This process also requires a few hops between main control center and plants for its completion. Its output would be the operation-schedule for the plant.

Keeping in view these processes, a possible higher-level process-map has been drawn as shown in fig. 2.

CONCLUSION

Older processes of *economic dispatch, unit commitment, load flow analysis, reservoir analysis,* are the individual tasks that may become a part of the larger objective, but they cannot be considered as processes. It can be clearly seen now from the *Process Map,* of an electrical power system, that the components of system-operation may be deceptralized. This would help in arriving at better decisions in a timely and more efficient manner. The presence of high-speed networks has made it possible to employ knowledge-based access of distributed databases.

It is mandatory to *Reengineer the Electrical Power System.* Only then can one take advantage of artificial intelligent techniques and build a *coupled expert system* [I] for solving the problem of "Optimal Operation of Electrical Power Systems.

FUTURE WORK

Economic operation of electrical power systems is an important issue, on which a research project is going on in the University of Engineering and Technology, Lahore, Pakistan, for developing new methodologies, utilizing decentralized artificial intelligence techniques. The present research paper is the 4th in the series. After preparation of the "Process Map", the next task would be the development of architecture of the databases required, and the communication manners in which they would interact with each other.

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SURFACE STRUCTURE OF A SANDY LOAM SOIL, AS AFFECTED BY LONG-TERM TILLAGE AND FERTILIZER IN THE POTOWAR PLATEAU OF PAKISTAN

M.S. Akhtar, A. Hussain**, M.A. Naeem** and S. Qureshi**

ABSTRACT

Changes of soil-structure of the rain-fed soils that result from continuous use of mechanized tillage and chemical fertilizer have not been documented in Pakistan. Long-term (5-year) moldboard and shallow (with tine-cultivator) tillage, and application of nitrogen and phosphorus (NP) and farmyard manure (FYM), separately or in combination, were studied for their effect on surface-structure of a sandy loam soil, classified as Typic Camborthid (Calcaric Fluvisols). In the surface horizon (Ap 0-11 cm), moldboard tillage compared to cultivator resulted in 0.04 Mg cm^{-3} lower bulk density (ρ_b). The combined application of NP-FYM under moldboard tillage resulted in the lowest ρ_b of the surface-soil. Moldboard tillage had lesser macro-porosity than shallow tillage and, therefore, the reduction in ρ_b with moldboard tillage was ascribed to an increase in < 60 μm porosity. Ponded and near-saturated infiltration was 15 to 30 mm h^{-1} greater with a combination of NP-FYM than with the NP treatment.

The cultivator tillage resulted in a larger mean pore radius and a greater number of macro-pores, with area of each pore class $\geq$ 60 μm radius than moldboard tillage. Similarly, farmyard manure, both alone and in combination with NP, resulted in a larger mean pore radius, greater number and area of all pores size classes than with no fertilizer and NP alone. The continuous use of NP reduced the mean pore radius and fraction of $\geq$ 60 μm radius pores, especially with moldboard tillage. Infiltration rate did not correlate with total porosity. Ponded and near-saturated infiltration corresponded better to the area of $\geq$ 380 μm radius pores. Infiltration at –40, –100, and –180 mm potentials correlated better with number of 380-150, 150-80, 80-60 μm radius pore classes, respectively. The long-term use of cultivator tillage and NP fertilizer with FYM resulted in a better soil structure than the moldboard tillage, especially without farmyard manure.

Keywords: *Surface soil structure; Macro-porosity; Saturated-, near-saturated, and un-saturated infiltration; Hydraulic conductivity.*

1. INTRODUCTION

Soil management practices influence soil-structure through changes in size and stability of aggregates and pore-size distribution, as well as its geometry (Norton, 1987) and, consequently, affect crop-production (Alakukku, 1996; Azooz et al., 1996). The two components of soil management: (a) tillage and (b) additions of organic matter play a vital role in maintaining soil-plant physical conditions in the root-zone. Tillage can pulverize compacted layers and improve soil permeability and percolation (Bennie and Botha, 1985), but the effect may not be sustainable in structurally unstable soils: Tillage with moldboard and chisel-plow initially creates greater volume of pores >150 μm, but the effect is only temporary (Hill et al., 1985; Benjamin, 1993). Multiple passes by tilling machinery can create compacted surface-layers with small size soil aggregates (Dexter, 1986) and reduced macropores (Ankeny et al., 1991). In contrast, no-tillage creates macro-pores in the surface layer over a longer period, which has been ascribed to enhanced faunal and microbiological activities (Doran, 1980; Drees et al., 1994). A long-term tillage effect on pore-size distribution has also been reported to depend on soil clay content (Heard et al., 1988).

Soil organic-matter encourages granulation, improving the tilth, increases porosity, which promotes water infiltration, and increases available water-capacity in mineral soils. High correlations between soil organic-matter and total porosity have been reported (Pikul and Zuzel, 1994). Increasing rates of manure-application improve physical conditions, encouraging rooting activity and saturated infiltration (Sommerfeldt and Chang, 1985; Darwish et al., 1995). Soil compaction reduces density of bio-pores (Alakukku, 1996) and a small increase in soil organic- matter reduces the compaction inflicted by heavy machinery (Soane, 1990). Approximately 3% organic matter is considered necessary for optimum soil physical conditions (Soane, 1990). In the arid sub-tropics, native concentration of stable organic-matter is low and, due to socio-economic factors, recycling of crop-residue is limited. Therefore, management of soil organic- matter is a critical issue in this region.

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Tine cultivation is used for both primary tillage and seedbed preparation in the rain-fed areas of the Potowar plateau of Pakistan. The traditional cultivator has 9 to 11 tines and is pulled with a 45 horsepower tractor. Continuous shallow tillage with tine cultivator has created a compact layer at 12-20 cm profile depth, with bulk density of 1.60 to 1.75 Mg m^{-3} in loam textures soils (Akhtar and Qureshi, 1999). Based on the agronomic-yield gain, ascribed to greater availability of water to plants from increased rainwater intake, primary tillage with moldboard is therefore recommended (Razzaq et al., 1989; Gill et al., 2000). On an average, 36% yield increase of wheat (*Triticum aestivum*) by moldboard tillage over the tine cultivator has been demonstrated (Razzaq et al., 1989; Gill et al., 2000). Changes in soil-structure created by these common soil- management techniques have never been determined in quantitative terms. Our objective was to determine the changes in soil-pore size-distribution and hydraulic characteristics, due to long-term tine cultivator or moldboard tillage and use of organic/inorganic fertilizer in the rain-fed area.

2. MATERIAL AND METHODS

2.1 Experimental site

The Crop Sciences Institute of the National Agricultural Research Center, Islamabad, Pakistan, initiated a study in July 1992 to determine crop-yield response of wheat-maize (*Triticum aestivum* and *Zea mays*, respectively) rotation to various long-term tillage and fertilizer treatments. The site was a Nabipur sandy loam soil series, classified as *Typic Camborthid* (*Calcaric Fluvisols*) at longitude 71.1°E and latitude 43.4°N. Mean annual rainfall in the area is 650 mm; a large proportion of it falls as a few monsoon storms during July and August, and the remaining proportion comes as gentle showers during the winter. The area has cool winters, with a low around 0 to 5°C and hot, dry summers, with a high around 40 to 45°C. The soil is developed from a mixed, calcareous alluvium, and is weakly differentiated, with native organic matter as low as <2.5g kg^{-1} (Khanzada, 1976).

2.2. Tillage and fertilizer treatments

Tillage operations and fertilizer application were done each year before planting wheat (2nd week of November) and maize (2nd week of July) under a permanent layout, with tillage as main plots and fertilizer as sub-plots. Shallow tillage consisted of two tine cultivations, followed by two plankings with a 100 kg wooden bar dragged behind a tractor-mounted tine-cultivator. The moldboard-tillage consisted of one operation with moldboard, followed by two plankings at planting times. Tillage depth was 10 to 12 cm in case of the tine cultivator operations and 20 to 25 cm in case of the moldboard tillage. Moldboard tillage is a conventional tillage in developed countries and the shallow tillage with a tine cultivator is close to reduced tillage.

The following four fertilizer-treatment combinations were applied in the sub-plots: (i) NP, 100-70-0 kg N-P-K ha^{-1} to wheat and 110-140-0 kg ha^{-1} to maize; (ii) FYM, 5000 kg ha^{-1} FYM to wheat; (iii) NP+FYM, NP plus FYM; and (iv) Control, without NP or FYM. Each treatment had 3 replicates, with a plot size of 17 × 6 m. A complete dose of each fertilizer-combination was evenly spread and mixed in the surface-soil at the time of seedbed preparation, before planting each crop.

2.3. Soil measurements

Infiltration characteristics and bulk-density of surface-soil (0-11 cm) were determined about 45 days after planting maize during September 1997. Soil-surface bulk-density was measured by placing a pre-calibrated Gamma (CPN 501) probe at 7.5 cm depth. Saturated infiltration was measured *in situ,* using a constant-head (+50 mm) well permeameter (Reynolds et al., 1985). The crusted surface (15 mm) was scraped off and a permeameter was installed in a 200 mm dia x 100 mm length PVC ring, inserted 25 mm into the ground. At steady state, four readings of drop in water-levels in the reservoirs were recorded at a 15 min time interval. From the steady-state rate of water-flow out of a cylindrical well, the infiltration flux, infiltration rate, field saturated hydraulic conductivity (K_{fs}), and matric flux potential (∅∅m) were calculated (Reynolds et al., 1985).

Infiltration characteristics of surface-soil in the potential (ψψ) range of –40 and –180 mm of water was measured, using a tension infiltrometer (Ankeny, 1992; Jarvis and Messing, 1995). Infiltration at close to 0 mm tension cannot be determined easily using a disk type infiltrometer; yet, it is required if information

on changes in macropores is needed. Soil strength at near zero potential may not support the weight of the permeameter (White et al., 1992) and collapse under pressure, yielding negative hydraulic conductivity at zero potential ($K\psi\psi o$). Infiltration rates at 0 and –250 mm of water were predicted by regressing infiltration data from the same surface at +50, –40, –100, and -180 mm water pressure heads. Infiltration rate (infiltration flux per unit surface area, L h^{-1}), hydraulic conductivity ($K\psi\psi i$), and matrix flux potential ($\varnothing\varnothing\psi\psi i$) were calculated from the infiltration flux (Q, $L^3 T^{-1}$) for the potential ($\psi\psi i$) pairs: (i) 0/–40 (ii) –40/–100, (iii) –100/–180, and (iv) –180/–250 mm of water. Three measurements for bulk density and infiltration were made in each plot.

Calculations for $K(\psi\psi)$ and $\varnothing\varnothing(\psi\psi)$ were done using the Poiseuille's equation, $Q = \pi\pi\ r^2\ K + 4\ r\ \varnothing\varnothing$, (Wooding, 1968), where K is hydraulic conductivity ($L\ T^{-1}$) and $\varnothing\varnothing$ matric flux potential ($L^2\ T^{-1}$) (Ankeny, 1992; Akhtar et al., 1999).

As an estimate of soil structure, macroscopic capillary length, λc, was calculated, following White and Sully (1987) and Ankeny (1992). Since $\lambda\lambda_c$ is a K-weighted mean soil-water potential (L), we can relate $\lambda\lambda c$ by the capillarity theory to obtain a characteristic pore dimension, λm, that controls the flow when infiltration occurs through the surface: $\lambda\lambda m = \sigma/\rho g\lambda\lambda_c$, where σ is the water surface tension (72.75 kg s^{-2}); ρ is the water density (1000 kg m^{-3}); g is the acceleration due to gravity (9.80 m s^{-2}); and $\lambda\lambda_c$, characteristic capillary length (Bouma, 1991; Ankeny, 1992).

Assuming cylindrical pores, an equivalent radius, r, is $2\sigma\cos\alpha/\rho g\psi\psi i$ (Danielson and Sutherland, 1986) where α is the contact angle and $\psi\psi_i$ is the water-potential level. Since water from a pore can be removed when suction exceeds the force acting to retain it, infiltration at $\psi\psi_{-40}$, $\psi\psi_{-100}$, $\psi\psi_{-180}$, and $\psi\psi_{-250}$ mm water-potential will exclude pores of equivalent radius, r > 380, 150, 80, and 60 μm, respectively, from the flow process. With known r, the number of effective pores per area (m^{-2}) is $8\ \mu\ I / \pi\rho g(r)^4$, where μ is the viscosity of water (kg m^{-1} s^{-1}), I is the infiltration- rate (m s^{-1}) at a given potential, and r is the minimum radius (m) for the pore class (Watson and Luxmoore, 1986; Wilson and Luxmoore, 1988). The infiltration rate associated with >380, 380–150, 150–80, and 80–60 μm pore radii was calculated as the difference between the infiltration- rate at $\psi\psi_{-0}$ and $\psi\psi_{-40}$; $\psi\psi_{-40}$ and $\psi\psi_{-100}$; $\psi\psi_{-100}$ and $\psi\psi_{-180}$; and $\psi\psi_{-180}$ and $\psi\psi_{-250}$, respectively. The total effective porosity, Φm ($\Phi m = N\ \pi\ r^2$) where N is the number of pores per m^2 and r is the pore radius, is a unitless quantity (Wilson and Luxmoore, 1988; Watson and Luxmoore, 1986).

1.4. Statistical analysis

SAS's General Linear Model (PROC GLM) was used for analysis of variance, to determine whether the surface-structure parameters varied by tillage and fertilizer treatments, as well as their interaction. Comparison of treatment means was made by Duncan's Multiple Range test (SAS Institute, 1992).

3. RESULTS

3.1 Soil bulk density (ρb)

The average ρb of the soil-profile with shallow tillage was 1.57 Mg m^{-3} and was 1.53 Mg m^{-3} with moldboard tillage. Tillage with moldboard resulted in a reduced bulk-density, specifically of Ap (0-11 cm) (Fig. 1) and BA (11-23 cm) horizons, compared to that of shallow tillage even when no fertilizer was applied (data on BA not presented). Continuous use of chemical fertilizer (NP) or farmyard manure (FYM) alone reduced ρb in the case of shallow tillage over the Control, but there was no further decrease with moldboard tillage. Further, combined application of farmyard manure and NP resulted in a significantly lower average ρ_b in the moldboard tillage, but not in the shallow tillage.

3.2. Saturated infiltration and hydraulic conductivity (K_s)

The saturated infiltration for Ap horizon is depicted in Fig. 2 at 50 mm potential on *x-axis*. The infiltration-rate in the shallow-tillage plots (mean of all fertilizer treatments) was greater than that of the moldboard plots. Saturated infiltration increased from 28 to 47 mm h^{-1} with a combined application of NP and farmyard manure, but moldboard tillage significantly ($p < 0.05$) modified the fertilizer effect (Fig. 2). The Control had the same saturated infiltration, both in the shallow and moldboard tillage, but application of NP alone, compared to that of Control, resulted in greater infiltration in shallow tillage and lesser in the

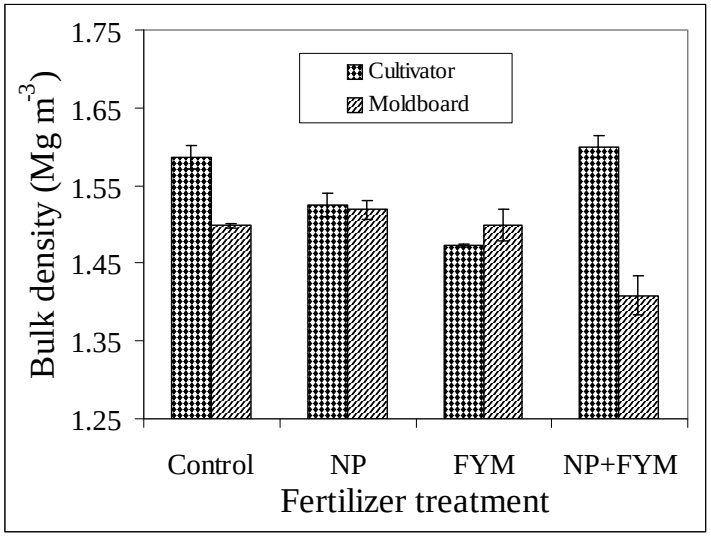

Figure - 1: Bulk density of the surface soil (0-11 cm) as affected by five-year tillage and fertilizer management: Control, no fertilizer; NP, nitrogen and phosphorus fertilizer; FYM, farmyard manure; and NP+FYM, combination of NP and farmyard manure. Bar equals stnadard deviation divided by the number of samples.

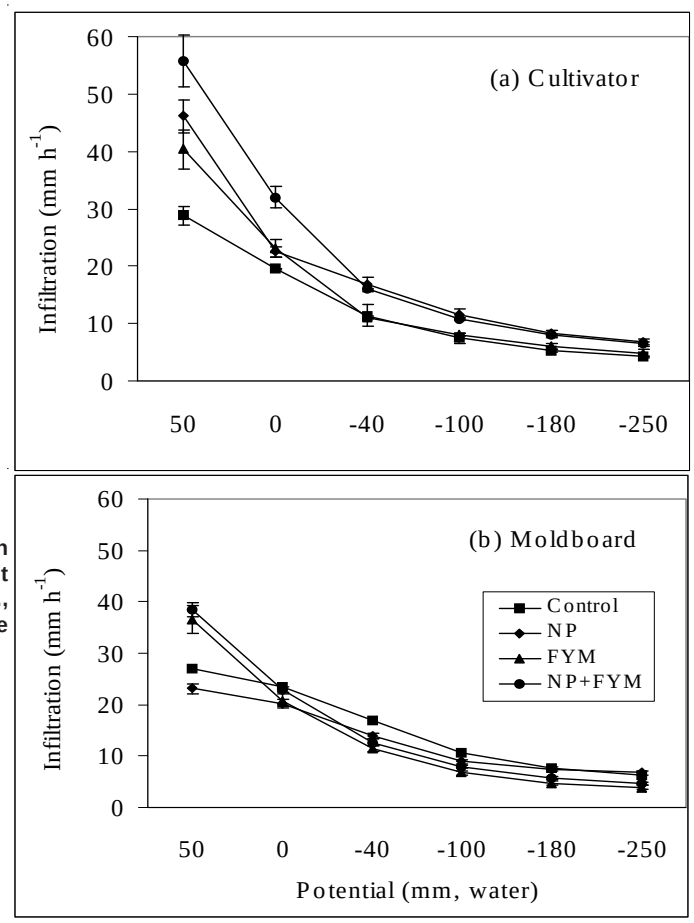

Figure - 2: Infiltration determined by Guelph permeability meter (+50 mm head) (Reynolds et al., 1985) and tension infiltrometer (White et al., 1992). Treatments and the bar, as defined in the caption of Fig. 1

moldboard tillage (Fig. 2a,b). Combined application of NP+FYM had the highest infiltration in shallow tillage. The saturated hydraulic conductivity had the same trend (data not presented).

3.3. Infiltration and hydraulic conductivity at near-saturation and under-saturation

In the shallow tillage plots, combined application of NP and farmyard manure resulted in the highest infiltration (33 mm h^{-1}) at near-saturated (0 mm water potential) (Fig. 2a). In the moldboard plots, all the fertilizer treatments had a similar infiltration-rate of 20 to 25 mm h^{-1} (Fig. 2b). Infiltration in the –40 to –250 mm potential range was greater with farmyard manure alone or in combination with NP in the shallow tillage plots, while in the moldboard plots the fertilizer-treatment difference was insignificant, except at –40 mm. At –40 mm potential, the control had greater infiltration rate than the other fertilizer treatments (Fig. 2b). The magnitude of difference in both cases decreased as the saturation decreased, with the potential setting growing more negative from 0 to –250 mm.

Hydraulic conductivity at 0 mm water-potential ($K_{\psi 0}$) varied from 10 to 18 mm h^{-1} in the shallow-tilled plots and 8.5 to 12.0 mm h^{-1} in moldboard tilled plots. The $K_{\psi -40}$ decreased to 4.0 mm h^{-1} in the shallow tilled plot and to 4.6 mm h^{-1} in the moldboard. The $K_{\psi -180}$ varied from 0.75 to 1.50 mm h^{-1} and the treatment-effect was non-significant. The fertilizer-treatments had significant effect on K_{ψ}, especially in the potential range of 0 to –40 mm water. The combined application of NP and farmyard manure resulted in a generally greater K, at all potential levels, than the other fertilizer treatments (Fig. 3a). The combined application of NP and FYM and application of NP alone resulted in significantly greater $K_{\psi -40}$ than the control and FYM alone in the shallow-tillage plots. In the moldboard plots, the control had greater $K_{\psi -40}$ than the other fertilizer treatments.

4. DISCUSSION & CONCLUSIONS

Change in distribution of pore-size, in response to the long-term treatments in the semi-arid environment is a significant finding of the study. Total porosity reflects soil-bulk, which is directly affected by tillage-methods (Heard et al., 1988). Our result on bulk-density conforms with Azooz et al. (1996), who reported greater bulk-density under no tillage (or reduced tillage) at the surface, compared to tilled soil. Further, the combined application of farmyard manure and NP resulted in a significantly lower average ρ_b than the control, in case of moldboard tillage but not in case of shallow tillage. Previously, a decrease in bulk-density as a result of long-term manuring (Sur et al., 1993; Ohu et al., 1994) and organic-matter application (Sommerfeldt and Chang, 1985) have also been reported. In this study, separate application of NP and farmyard manure also reduced the bulk-density over no fertilizer, which could be ascribed to better rooting-activity in the presence of optimum nutrients.

Total porosity realized from the bulk-density was the greatest in the moldboard plots receiving a combined application of NP and FYM, and the lowest in shallow tillage receiving the same treatment; but our results on macro-porosity, discussed later, did not support this conclusion. Bulk-density was determined by placing the radiation-source at 5.5 cm depth and, consequently, the values are average of 0-11 cm layer, while actually there may be a gradient of bulk-density within the 0 to 11 cm surface layer.

Average saturated infiltration and hydraulic conductivity (K_s) of the soil-profile was greater with the moldboard tillage than with the shallow tillage (Akhtar et al., 2001), but the reverse was true in the surface-soil. However, the K_s values were comparable to the reported values on another sandy loam under conventional tillage and no tillage, respectively (Azooz et al., 1996). Contradictory observations of tillage-effect on infiltration (and bulk density) do exist in literature. Greater saturated infiltration with moldboard tillage, compared to zero tillage and chisel (Heard et al., 1988), greater K_s under zero-tillage than the conventional moldboard tillage (Chang and Lindwall, 1992); and no difference between zero-tillage and moldboard (Sing et al., 1991); have all been reported. The general consensus is that, initially, zero-tillage (or the reduced tillage) has greater bulk-density and lower infiltration than moldboard tillage, but the condition reverses with time, due to increased biological activity in the intact surface (McCoy et al., 1994).

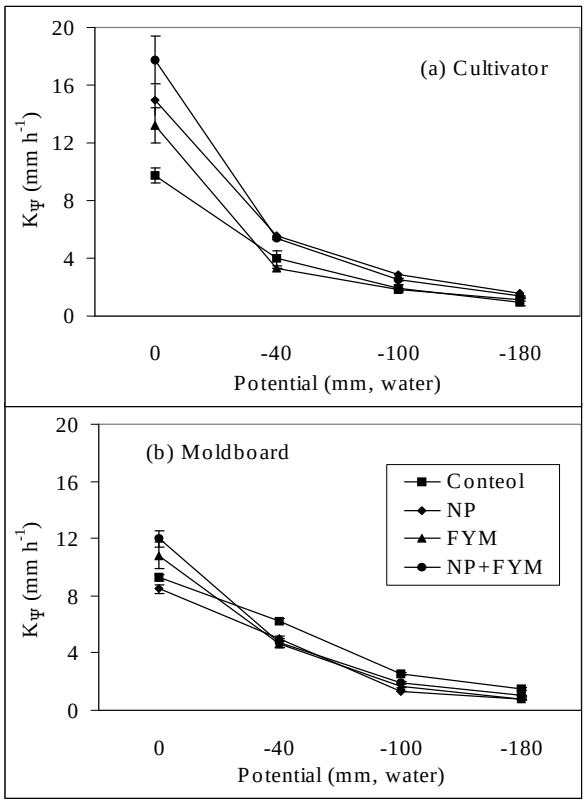

Figure - 3: Hydraulic conductivity at various potentials (Ankey, 1992). Treatments and the bar, as defined in the caption of Figure 1.

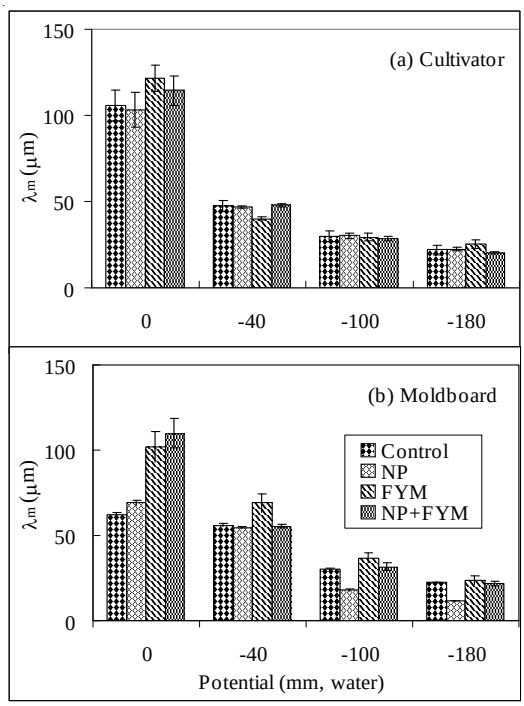

Figure - 4: Characteristics mean pore radii (Ankeny, 1992) as affected by the long-term treatments. Treatments and the bar as defined in the caption of Figure 1.

Saturated infiltration showed contradiction with total-porosity values determined from the bulk-density, e.g., the highest infiltration rate should be in the moldboard plots receiving combined application of NP and FYM, as these plots had the lowest bulk density (Fig. 1 and 2). This discrepancy may be due to either of two reasons: gradient in bulk-density of 0 to 11 cm layer (resulting in different values for the 0-5 cm layer and an average value of 0-11 cm, or macroporosity/pore continuity playing a stronger role in infiltration than total porosity (Singh et al., 1991). Infiltration rate and, consequently, hydraulic conductivity decreased as the potential decreased from 0 to –250 mm (Fig. 2 and 3), which was due to sequentially emptying the smaller and smaller pore-sizes as the size of the largest water-filled pores is inversely proportional to potential (Ankeny, 1992; Jarvis and Messing, 1995). In the given potential-level, effect of the long-term fertilizer and tillage treatments on infiltration was significant (Fig. 2), although the magnitude of difference decreased as the saturation decreased, with the potential setting growing more negative. The combined application of NP and FYM under shallow tillage had the highest near-saturation infiltration, while the control had the lowest (Fig. 2a), which may reflect greater porosity created by greater biological activities in the presence of organic matter. In the moldboard plots, treatment effect of FYM compared with the control was somewhat masked, due to overturning of the surface soil (Fig. 2b).

Hydraulic conductivity at near-saturated condition (0 water potential) varied more with both tillage and fertilizer-treatments than that of K at –100 and –180 mm water potential. The shallow tillage (cultivator) has greater pore-continuity than the moldboard tillage (Logsdon et al., 1990; Carter, 1992). Another study on a silt loam soil, where only cultivator tillage was done, reported approximately two times greater infiltration at –40 to –180 mm potential, due to long-term use of FYM and wheat-straw, compared to no organic matter application (Akhtar et al., 1999). An increased unsaturated hydraulic conductivity, due to long-term manuring (Ohu et al., 1994; Mbagwu, 1992) and other organic-matter sources (Obi and Ebo, 1995) has been reported and attributed to increased total porosity.

From the infiltration-data obtained at various potentials, we draw information on porosity and, particularly, the pore-size distribution. The capillarity equation gives the largest pore radius that can conduct water at a given potential. Therefore, at a given potential, pores varying in size from that defined by the equation to infinitesimally small would all be conducting water. Representative mean pore-radius (λ_m) is a characteristic mean pore-dimension that controls infiltration in the given range and has the utility for quantifying soil-structure and temporal changes in soil structure (Ankeny, 1992). At saturation, when all pores were conducting water, FYM had 120 μm λ_m compared to that of 103 μm of NP in the cultivator plots (Fig. 4a,b). It is obvious that characteristic pore-radius decreased with continuous use of chemical fertilizer under the moldboard tillage.

At –40 mm water-potential, when flow was through all the pores <380 μm, the shallow-tillage plots had λ_m varying between 28 and 31μm and the fertilizer-treatment effect was non-significant, while it was 54 to 69 μm in case of moldboard tillage. Also, the FYM treatment with and without NP had significantly greater λ_m than the other fertilizer treatments under the moldboard tillage (Fig. 4b). Therefore, continuous use of moldboard with chemical fertilizer (NP) without organic matter appears to have reduced mean pore-radius, especially in the range of macroporosity.

The λ_m at various potentials conforms to a previous study on a silt loam soil in the area, where 70 μμm at –40 mm potential and 30 μμm at –180 mm potential were reported (Akhatr et al., 1999). The λ_m also conforms to that of White et al. (1992). The largest difference in λ_m between FYM and NP treatments was in the bigger pore class. The study supports the conclusion of White et al. (1992) that tillage and biological activities have their most pronounced effect on size of connected pores of nominal pore-radius about 750 μm. Drees et al. (1994) reported average pore size in their no-till soil greater than their moldboard tillage soil, as determined through image analysis of thin-sectioned soil.

Maximum number of effective pores per m^2 surface soil at a given potential was calculated, using Poiseuille's equation (Wilson and Luxmoore, 1988; Watson and Luxmoore, 1986). The number of pores of > 380 μm radius were, on a $\log_{(10)}$ scale, 1.4 to 1.6, as compared to 2.6 to 2.8 of 150-80 μm size pores. The pores increased in number logarithmically as the

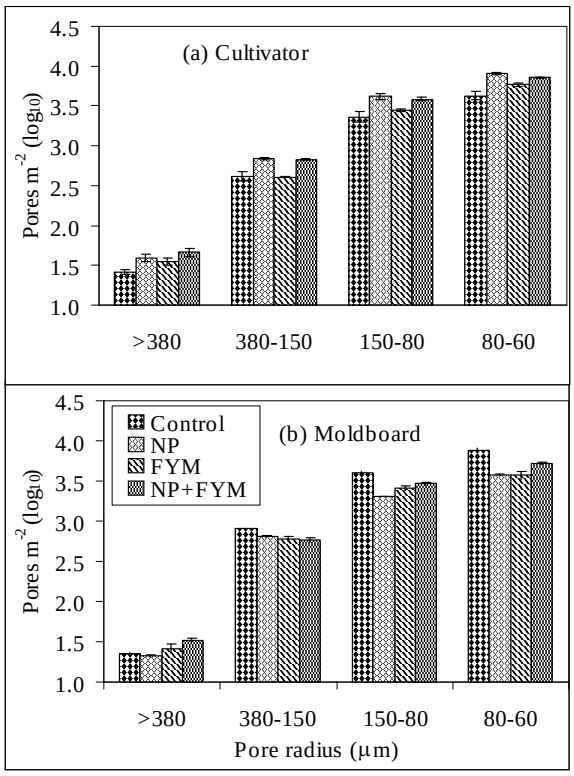

Figure - 5: Number of various size-class pores in a unit surface area (Wilson and Luxmoore, 1988) as affected by the long-term treatments. Treatments and the bar, as defined in the caption of Fig. 1

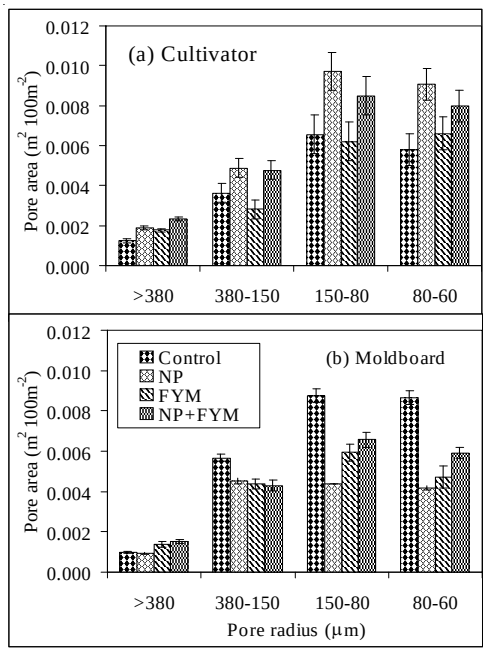

Figure - 6: Area of various size-class pores in unit surface area (Wilson and Luxmoore, 1988), as affected by the long-term treatments. Treatments and the bar, as defined in the caption of Fig. 1

pores radius decreased (Fig. 5). The number of pores participating in infiltration at –100 and -180 mm water potential were greater (in number) than that of at 0 to –40 mm, although infiltration was greater in the later case. The result conforms to the conclusion of Beven and Germann (1982), Wilson and Luxmoore (1988), and Logsdon et al. (1990) that fewer macropores have a great influence on the flow, although they are a small fraction of the total porosity. Therefore, in practice, total porosity may have less utility than pore-size distribution.

Thirty to 70 pores of ≥ 380 μm radius m^{-2} found in this soil (Fig. 5) fall within the general range previously determined by various techniques (McCoy et al., 1994). Smettem and Collis-George (1985) reported 37.5 hydrologically active macropores (≥ 220 μm radius) m^{-2}. Wilson and Luxmoore (1988) reported 94 and 183 pores ≥ 750 μm size pores in two Australian watersheds. Eighty pores of 25-125 μm radius in m^2 covering 20 m^2 area in 100m^2 in a long-term no-till plot and 91 pores covering 24 m^2 area in 100 m^2 in a moldboard plot was reported by Drees et al. (1994). Tillage and fertilizer treatment effect on the number of pore in all the pores size classes was significant (Fig. 5a,b). The shallow tillage had greater number of ≥ 380 μm pores than the moldboard tillage but the later had larger number of 380-150 μm size pores (Fig. 5a,b). In the shallow tillage plots, application of NP with and without FYM generally had a greater number of pores in all pore size classes than the control and only FYM plots (Fig. 5a). In the moldboard plots, the control had a greater number of pores in all size classes except > 380 μm (Fig. 5b). It appears that thoroughly mixing FYM in the root-zone, which was not possible in case of shallow tillage, is important for increasing number of pores with manure application.

Treatment effect on pores of ≥ 380 μm radius was of special interest due to their influence on near-saturation infiltration. The lowest number of this size class was found in the NP treatment under the moldboard tillage and the highest in the case of the combined application of NP and FYM with the shallow tillage (Fig. 5a,b). Within the moldboard plots the highest number of ≥ 380 μm size pores class was found in the case of the combined application of NP and FYM and the lowest in the NP treatment (Fig. 5b).

Effective porosity (Φ) is a unit-less quantity and can be thought of as an aerial coverage by a given pore size class to surface area (Wilson and Luxmoore, 1988). This method for estimating soil macroporosity has assumptions including (i) laminar flow of pure water, (ii) smooth cylinderical pores, and (iii) the pore radius determined by capillary theory. With the hidden discrepancy that the method ignores the effect of pore length on infiltration, the approach does provide estimates of equivalent soil porosity classes (Wilson and Luxmoore, 1988).

In the shallow tillage plots, aerial coverage by ≥ 380 μm pores were in the range of 1.22 x 10^{-3} in the control to 2.34 x 10^{-3} in the NP+FYM and 1.0x10^{-3} in the control to 1.52 x 10^{-3} in the NP+FYM in the moldboard plots (Fig. 6). Two forest soils had 1.7 x 10^{-4} and 3.2 x 10^{-4} Φ associated with > 750 μm pores and 1.5 x 10^{-3} and 1.2 x 10^{-3} associated with 110 μm pores (Wilson and Luxmoore, 1988). Edwards et al. (1988) reported 0.005 to 0.003 m^2 m^{-2} of surface area consisted of > 150 μm radius pores. Our Φ associated with various pore size classes provides reasonable comparison to the values. In the shallow tillage plots NP with and without manure had a greater Φ of all size classes than that of control and the only manure treatment (Fig. 6a). In the moldboard plots, combined application of NP and FYM had a greater Φ than that of NP only but lower than the control except for ≥380 μm pores class (Fig. 6b).

SOME CONCLUSIONS

Finally, we compare tillage and the fertilizer treatments for their effect on total effective macro-porosity (Φ_T), which is defined as the sum of Φ associated with ≥ 60 μm size pore. The moldboard plots under the control had a greater Φ_T than the corresponding shallow-tillage plots (Fig. 7). This difference is very well reflected in bulk-density values of the two treatments (Fig. 1). Further, when only chemical fertilizer (NP) was applied, the Φ_T decreased drastically in the moldboard plots, compared to that of the shallow tillage plots (Fig. 7). There was no statistical difference between the moldboard and shallow tillage when only FYM was applied, and both had approximately equal bulk density (Fig. 1 & 7). When NP and FYM were applied in combination, the shallow-tillage had a greater Φ_T than the moldboard tillage, although bulk- density was less in the later

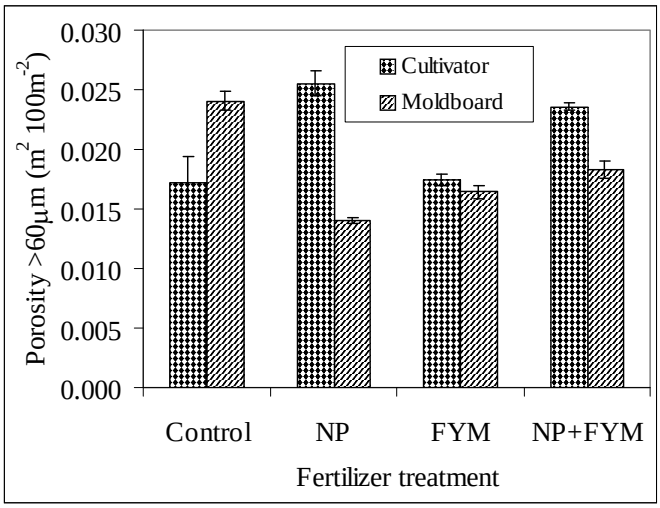

Figure - 7: Macroporosity (area of pores > 60 μm), as affected the long-term treatments. Treatments and the bar, as defined in the caption of Fig. 1

treatment combination. This suggests that lower bulk-density (greater total porosity) in the moldboard was due to a greater micro-porosity, (pores <60 μm radius). It would be of interest to compare number and area of macropores per unit surface to infiltration data. Infiltration at +50 mm head corresponds better to the area of ≥ 380 μm radius pores than the area of any pore size class or total macro-porosity in both the shallow tilled and moldboard tilled plots (Figs. 2, 6, and 7). Infiltration at –40, –100, and –180 mm potential settings conform with Φ associated with 380-150, 150-80, and 80-60 μm radius pore classes, respectively.

Our data point to

(i) conservation of macroporosity and surface-soil structure, with long-term use of the shallow-tillage with a tine cultivator and

(ii) deterioration of the same with continuous use of chemical fertilizers under moldboard tillage, especially, when no organic matter is incorporated into the farming system.

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THE EFFECT OF SUGAR ON SETTING-TIME OF VARIOUS TYPES OF CEMENTS

Bazid Khan and Bulent Baradan***

ABSTRACT

The objective of this research is to investigate the influence of sugar s of different origins (Beet & Cane) on the setting times of cement pastes. Sugar is incorporated with three different types of cements under three different curing conditions (Temp. & R.Humidity).

The test results revealed that, under normal curing conditions (Temp.=22^{0}C & R.H.≅60%), the efficiency of sugar in retarding cement setting becomes higher with increasing sugar-content upto a certain limit. However, with further increase in sugar content, its retarding efficiency started to decrease, until at certain higher content it showed reverse effects (i.e, it accelerated the cement setting). Furthermore, sugar causes higher retardation when added a few minutes after the mixing of water and cement.

INTRODUCTION

When water is added to cement, it sets and hardens gradually under normal climatic conditions. But in some countries, including Pakistan, higher summer temperatures, low relative humidity and hot wind blowing cause rapid evaporation of water from the fresh concrete surface. Consequently concrete sets earlier and no proper time is left available for concreting operations. For example, it has been reported that, when the temperature of cement mortar wit a water/ cement (w/c) ratio of 0.6 is increased from 27.8^{0}C to 45.5^{0}C both the initial and final setting times are nearly halved[1]. Further problems also arise such as rapid decrease of slump[2], formation of cold joints and plastic shrinkage cracking[3], increased difficulty in air entrainment[2], enhanced permeability and reduced durability[4], corrosion of steel[5], and reduction in ultimate strength of concrete[6].

Inorder to provide proper time for concreting operation, especially when unavoidable delays between mixing and placing occur, and to save concrete from other detrimental effects of adverse climatic conditions, cement set retardation/or use of retarding admixtures is necessary. " An admixture is a material other than water, aggregates, hydraulic cement and fiber reinforcement, used as an ingredient of concrete or mortar and added to a batch before or during mixing. A retarding admixture/retarder is an admixture that retards the setting of cement concrete, mortar or grout[7]".

A retarding admixture causes cement set retardation by the following mechanisms:

1) Adsorption of the retarding compound on the surface of cement particles, forming a protective skin, which slows down hydrolysis;
2) Adsorption of the retarding compound onto nuclei of calcium hydroxide, poisoning their growth, which is essential for continued hydration of cement after the end of induction period;
3) Formation of complexes with calcium ions in solution, increasing their solubility and discouraging the formation of the nuclei of calcium hydroxide, refereed to in (2);
4) Precipitation around cement particles of insoluble derivatives of the retarding compounds formed by reaction with the highly alkaline aqueous solution, forming a protective skin[8].

Retarding admixtures are mainly based on materials having lignosulfonic acids and their salts, hydroxy-carboxylic acids and their salts, sugar and their derivatives and inorganic salts, such as borates; phosphates, zinc and lead salts[9].

Sugar is a carbohydrate, a substance composed of only carbon, oxygen and hydrogen. Sucros, fructose, dextrose, lactose and other 'Oses' are members of this chemical class. It occurs in sugar cane and sugar beet. The basic unit of carbohydrate is a linear chain of four to seven carbon atoms with a hydoxyl group on each one, the terminal carbon being an aldehyde.

Owing to the retardation of ordinary Portland cement, sugar falls into three categories: non-retarding, good retarders and most effective retarders. The non-reducing sugars, α-methyl glucoside and α-α trehalose, are effectively non-retarding; the reducing

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sugars, glucose; maltose, lactose and celloboise, are grouped together as good retarders, while the non-rdeucing sugars (which have a five-member ring) sucrose and raffinose are far the most effective retarders. Sugars have been categorized as 'cement destroyer' and when small amounts of sugar (1% by weight of cement) are added to Portland cement paste at the onset of mixing, hardening may be delayed indefinetly[10].

The retarding action of sugar is probably by the prevention of the formation of calcium silicate hydrate (CSH)[2].

EXPERIMENTAL PROGRAM

Materials: Two types of sugars of different origins (sugar beet & sugar cane) and three different types of cements, designated as PKC/A42.5, PKC/B32.5 and PC42.5 (According to Turkish Standard No.20), were used. Their oxide and compound compositions are shown in Table 1.0.

Table - 1.0: Oxide and Compound composition of cements

Name	Abbreviation	PKC/A 42.5	PKC/B 42.5	PC 42.5
Silica	Sio_2	23.79	33.06	19.30
Alumina	Al_2O_3	6.33	7.43	5.38
Ferric oxide	Fe_2O_3	3.52	3.33	2.89
Lime	CaO	57.20	45.03	62.78
Magnesia	MgO	0.69	0.90	1.66
Sodium	Na_2O	-	0.10	0.55
Potassium	K_2O	1.03	1.46	0.75
Sulfuric Anhydride	SO_3	2.00	2.07	3.17
Chlorine	CL^-	0.019	0.0266	0.0089
Loss on ignition	L.O.I	2.14	4.21	3.29
Undetermined	-	3.28	-	-
% Free lime	% F.CaO	1.37	0.39	0.77
Insoluble residue	I.R	-	29.06	0.42
Soundness (mm)	-	2.00	3	1.00
Specific gravity	-	3.03	-	3.08
Weight per liter (g/lt)	-	984	910	1050
Fineness-specific surface (cm^2/g)	-	3661	4963	3759
Lime saturation factor	L.S.F.	-	196.35	99.15
Hydraulic modulus	H.M.	-	3.05	2.31
Silica modulus	S.M.	-	0.37	2.29
Alumina modulus	A.M.	-	2.23	1.86
Tricalcium silicate	C_3S	-	-	59.51
Dicalcium silicate	C_2S	-	-	10.76
Tricalcium aluminate	C_3A	-	-	9.37
Tetracalcium aluminoferrite	C_4AF	-	-	8.79

Procedure

The setting time tests were performed on cement paste of standard consistency. The quantity of cement and water used per test for each type of cement are:

Type of cement	Amount of cement9g)	Water (ml)	w/c ratio
PKC/A42.5	400	130	32.50
PKC/B32.5	385	130	33.75
PC42.5	400	110	27.50

For one type of tests, the sugar was dissolved in the mixing water before adding it to cement. Vicat apparatus was used and Turkish Standard(TS) No.19 was followed for taking initial and final setting-times readings. According to TS-19, initial set is said to have taken place when the needle(1.13mm dia.) of Vicat apparatus ceases to pass 3-5 mm above the bottom of cement paste taken in a Vicat mould (top internal dia.= 80mm, bottom int. dia.= 90mm, height = 40mm). Final setting is said to have occurred when the needle penetrates the cement paste to a maximum depth of 1mm. In both the cases, the setting-time is reckoned from the moment when the mixing-water is added to the cement.

For other type of tests, half of the mixing-water containing no sugar was added to the cement and in the remaining half of the mixing-water, sugar was dissolved and added, 10 minutes later on, to the cement.

Curing Conditions

Inorder to simulate the approximate outdoors climatic conditions, the following three categories of curing conditions were provided, to the test specimens:

1) Curing condition first (CC-I): Temperature = 22^{0}C, Relative Humidity = 55-65%
2) Curing condition second (CC-II): Temperature = 35^{0}C, Relative Humidity = 35-45%
3) Curing condition third (CC-I): Temperature = 50^{0}C, Relative Humidity = 25-35%

Test Data And Presentation Of Results

Setting-time tests with varying sugar-contents (expressed as a percentage by weight of cement) were performed, under the specified curing conditions. The average of three test readings was taken as the final reading. These are shown in the following Tables 1.1 to 1.9 and Figures 2.1 to 2.6 together with Tables 1.10, 1.11 and Figs. 1.7 and 1.8 for effect of stage of sugar incorporation and of cane sugar and beet-sugar.

A) RESULTS FOR CEMENT PKC/A42.5

Table - 1.1: Setting time and relative retarding effects of sugar on cement setting under CC-I

Sugar (%)	000	0.04	0.05	0.06	0.70	0.10	0.20	0.25	0.30	0.4/0.5
Initial setting time(mins)	143	292	325	512	660	840	590	260	42	20
Final setting time(mints)	204	364	402	569	720	960	790	649	72	40
Initial set retardation	1	2.04	2.27	3.58	4.62	5.87	4.13	1.82	0.29	0.14
Final set retardation	1	1.78	1.97	2.79	3.53	4.71	3.87	3.18	0.35	0.20

The results of Table 1.1 are graphically shown in Figures 1.1 and 1.2.

Table 1.2 Setting time and relative retarding effects of sugar on cement setting under CC-II

Sugar (%)	000	0.04	0.05	0.06	0.70	0.80
Initial setting time(mins)	96.5	172	256	309	331	417
Final setting time(mints)	131.5	214	306	354	383	481
Initial set retardation	1	1.80	2.68	3.24	3.47	4.37
Final set retardation	1	1.63	2.33	2.69	2.91	3.66

Table 1.3 Setting time and relative retarding effects of sugar on cement setting under CC-III

Sugar (%)	000	0.04	0.05	0.06	0.70	0.80
Initial setting time(mins)	78	156	184	238	278	323
Final setting time(mints)	102	187	216	280	319	392
Initial set retardation	1	2.00	2.36	3.05	3.56	4.14
Final set retardation	1	1.83	21.2	2.75	3.13	3.84

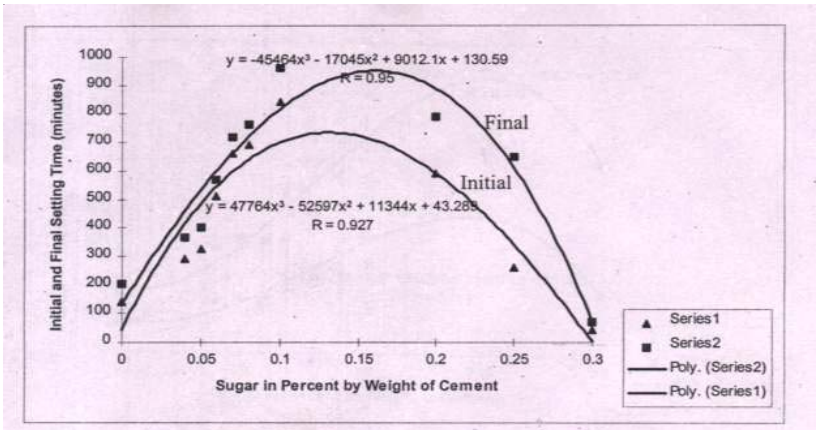

Figure - 1.1: Effect of Sugar on Setting Time of Cement (PKC/A 42.5) Under CC-I

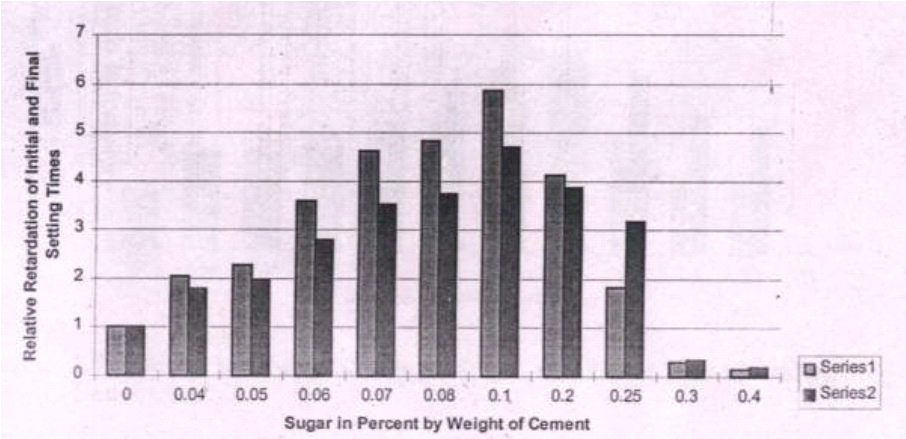

Figure - 1.2: Relative REtarding Effect of Sugar on Setting of Cement (PKC/A 42.5) Under CC-1

B) RESULTS FOR CEMENT PKC/B32.5

Table 1.4 Setting time and relative retarding effects of sugar on cement setting under CC-I

Sugar (%)	000	0.04	0.05	0.06	0.70	0.80	0.09	0.10	0.20	0.40	0.50
Initial setting time(mins)	88	148	157	164	189	204	293	342	178	125	113
Final setting time(mints)	172	300	333	322	402	494	517	660	550	430	395
Initial set retardation	1	1.68	1.78	1.87	2.15	2.32	3.33	3.90	2.02	1.42	1.28
Final set retardation	1	1.74	1.94	1.86	2.34	2.87	3.00	3.84	3.20	2.50	2.30

The results of Table 1.4 are graphically shown in Figures 1.3 and 1.4

Table 1.5 Setting time and relative retarding effects of sugar on cement setting under CC-II

Sugar (%)	000	0.04	0.05	0.06	0.70	0.80
Initial setting time(mins)	70	111	131	129	144	157
Final setting time(mints)	132	191	210	215	227	250
Initial set retardation	1	1.59	1.87	1.84	2.06	2.24
Final set retardation	1	1.45	1.59	1.63	1.72	1.89

Table 1.6 S ent setting under CC-III

S										.80	0.09
I										3	82
F										51	133
I										.45	1.28
F										.47	1.29

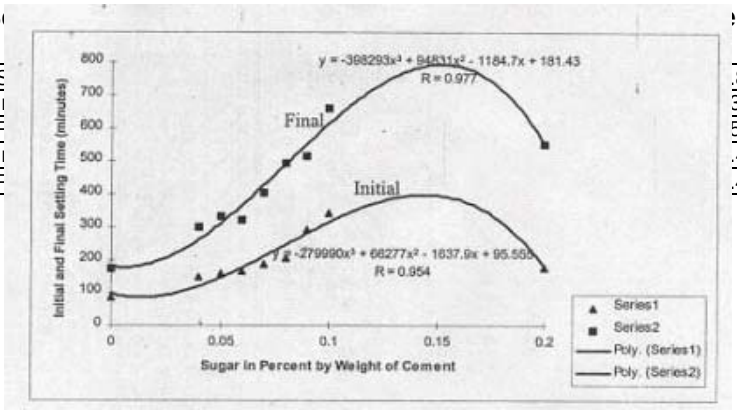

Figure - 1.3: Effect of Sugar on Setting Time of Cement (PKC/B 32.5) Under CC-I

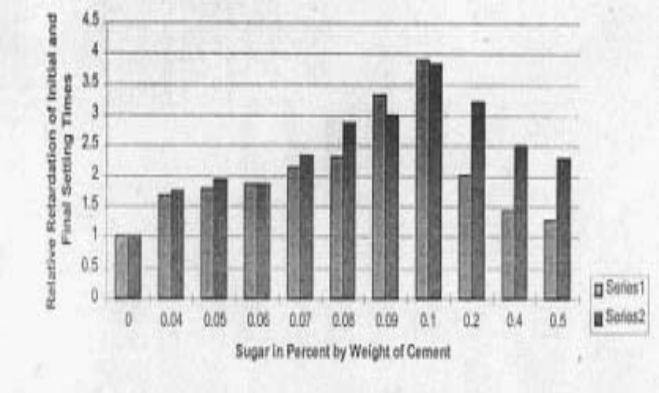

Figure - 1.4: Relative Retarding Effects of Sugar on Cement (PKC/B 32.5) Setting Under CC-I

C) RESULTS FOR CEMENT PC 42.5

Table 1.7 Setting time and relative retarding effects of sugar on cement setting under CC-I

Sugar (%)	000	0.04	0.05	0.06	0.70	0.10	0.20	0.30	0.40	0.50-2.0
Initial setting time(mins)	126	263	295	486	528	507	512	198	41	12
Final setting time(mints)	179	331	386	554	618	692	780	527	63	15
Initial set retardation	1	2.09	2.34	3.86	4.19	4.02	4.06	1.57	0.33	0.095
Final set retardation	1	1.85	2.06	3.09	3.45	3.87	4.36	2.94	0.35	0.08

The results of Table 1.7 are graphically shown in Figures 1.5 and 1.6

Table 1.8 Setting time and relative retarding effects of sugar on cement setting under CC-II

Sugar (%)	000	0.04	0.05	0.06
Initial setting time(mins)	122	238	273	327
Final setting time(mints)	148	268	305	365
Initial set retardation	1	1.95	2.24	2.68
Final set retardation	1	1.81	2.06	2.47

Table 1.9 Setting time and relative retarding effects of sugar on cement setting under CC-III

Sugar (%)	000	0.04	0.05	0.06
Initial setting time(mins)	91	154	201	222
Final setting time(mints)	108	182	238	255
Initial set retardation	1	1.69	2.21	2.44
Final set retardation	1	1.69	2.20	2.36

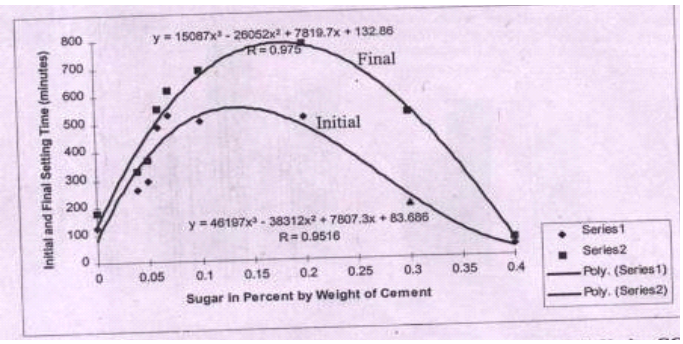

Figure - 1.5: Effect of Sugar on Setting Time fo Cement (PC 42.5) Under CC-I

Figure - 1.6: Relative Retarding Effect of Sugar on Setting of Cement (PC 42.5) Under CC-I

Table 1.10 Effect of the stage of sugar-incorpo

Cement type	Sugar(%)	Sugar added 10 minutes aft water			
		Initial setting	F		
PKC/A42.5	0.04	307			
	0.05	448	5		
PKC/B32.5	0.04	246	3		
	0.05	319	442	215	297

The results of the Table1.10 are graphically shown in Figure 1.7

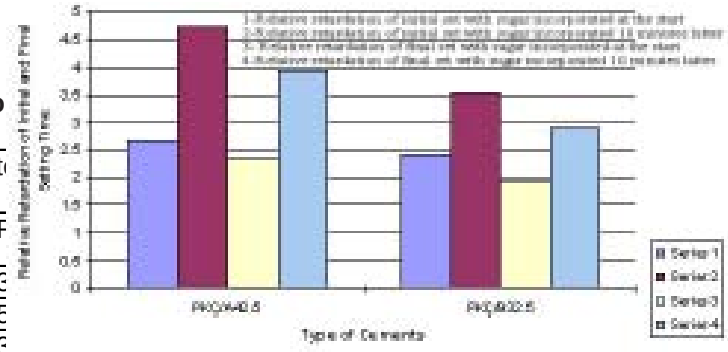

Figure 1.7: Effect of the Stage of Incorporation of 3 Sugar (0.05%) on Cement Setting Under CC-II

ment-setting

Sugar (%		Beet sugar	
		al set	Final set
0.04			220
0.05			306

The resu

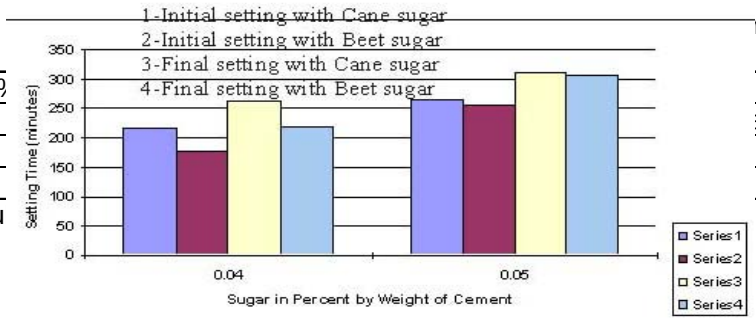

Figure - 1.8: Effect of Cane and Beet Sugar on Cement Setting

CONCLUSIONS & FURTHER RESEARCH SUGGESTIONS

Conclusions:

1) Setting of cement was retarded by incorporation of sugar in cement under all conditions of curing. Consequently, setting-times were extended. The extension in setting-time was increasing with an increase in sugar content up to a certain limit (≅0.15%) and then started to drop with further increase in sugar content. Sugar accelerated the cement-setting when a higher sugar content(≥0.3%) was used
2) Relatively low retarding tendency was shown by sugar under the second and third curing conditions.
3) 0.15% sugar-content acted as an Optimum Sugar Content for retarding the setting.

It was further noted that:

a) Practically same retarding tendency was shown by both Cane sugar and Beet sugar.
b) Increased retardation was caused by sugar when it was added to the cement a few minutes after mixing of cement and water.
c) The effect of sugar on cement setting is dependent upon the chemical composition of cement.

Following are some suggestions for further research:

There is need to examine other physical and chemical properties of sugar-incorporated cement pastes/ mortars, such as strength, shrinkage, permeability, etc.

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PROSPECTS OF SEQUENTIAL BIOLOGICAL CONCENTRATION FOR SALINITY-MANAGEMENT IN PAKISTAN

M.A. Kahlown, M. Azam** and John Blackwell****

ABSTRACT

Salinity is recognized as one of the major problems faced by the irrigated agriculture of Pakistan. According to a recent study, 150 million tons of salts are annually added in the soil-matrix, while about 80 million tons are removed through leaching. Extensive efforts had been made to combat the problem of salinity and waterlogging in the past. Upto 1995, about 51 Salinity-Control and Reclamation Projects (SCARPs) were built at a cost of Rs. 190 billion. These projects could not overcome the salinity and waterlogging problems completely. Recent unprecedented growth of private tubewells has further aggravated the salinity-situation. A recent study shows that about 70 percent of 565,000 private tubewells installed to meet demand for irrigation-water are pumping sodic water. Due to the non-availability of proper saline effluent-disposal, saline ground-water is disposed off into waste- land and evaporation basins, which have met with limited success.

In order to safely remove the salts from the soil-matrix, Sequential Biological Concentration (SBC) approach has been successfully tried in Australia. The SBC is a system aimed at optimizing the use of saline ground water before evaporative disposal. In Pakistan, many options are being evaluated to use saline water. These include saline agriculture and aqua-culture. The SBC approach takes out salts from the ecosystem at farm-level, to reduce the burden of salts at the regional level. In this paper, the SBC concept and its prospects in Pakistan are discussed in detail. The experience gained on SBC in other countries is also discussed.

1. INTRODUCTION

The Indus irrigation-system is responsible for delivering the irrigation-supplies to about 16 million hectare (Mha) of the irrigated area. The irrigation-system comprises the Indus River and its tributaries, 4 major storage reservoirs, 23 barrages, 12 link canals, 45 canal-commands and about 100,000 watercourses. The length of the canals and watercourses and field ditches is about 60,800 km and 1.6 million-km respectively (Table-1). In this system, about 5 billion cubic meter of river-water is diverted annually. The average inflows and water use is summarized in Table 2. Present ground-water balance in Indus Basin is shown in Figure 1. In this system, about 5 billion cubic meter of river-water is diverted annually. The average inflows and water-use is summarized in Table 2.

The overall irrigation conveyance-efficiency is estimated at below 40 percent, with maximum losses occurring in the watercourses and fields. This high loss of water has been depriving the farmers of the most precious input for agriculture and causing the problems of waterlogging and salinity. At present, about 3.5 Mha of land is in need of irrigation-water, whereas 2.93 Mha and 6.18Mha are badly affected with waterlogging (Table-3) and salinity (Table-4), respectively.

According to a recent study, 150 million tons of salts are annually added in the soil-matrix, while about 80 million tons are removed through leaching. Each acre thus receives about 0.6 ton of additional salts every year. The schematic diagram of incoming distribution of salt is shown in Figure 2. Recent unprecedented growth of private tubewells has further aggravated the salinity situation. A recent study shows that about 70 percent of 565,000 private tubewells installed to meet irrigation water-demand are pumping sodic water, which has further aggravated the salinity-situation in the irrigated agriculture of Pakistan. Kahlown et al. (2002) indicated that water-table depth less than 1 meter had significant effect on yield of almost all the crops with the exception of rice. Moreover, the combined effect of waterlogging and salinity was found more harmful to crop-yield than the individual effect of waterlogging (Kahlown and Azam, 2002). Using groundwater of poor quality for irrigation has further aggravated the problem of soil salinity and sodicity as 70 percent of the tubewells are pumping sodic water. It is estimated that 38% of the gross command-area is waterlogged and 14% is saline. About 25 percent reduction in the yield of major crops is attributed to soil salinity only (Haq et al., 1997).

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Table-1: Main Features of Indus Irrigation System

Item	Quantity
Storage reservoirs Live capacity (designed)	4 19.3 Bm^3
Barrages, headworks and siphons	23
Main irrigation canals Command area Length (including distribution system)	45 16.67 Mha 60,800 Km
Farmers Watercourses Length	100,000 1.6 million Km

Source: Tarar, 1999

Table-2: Average Inflows and Water Use in the Indus Basin

Water Inflow	Quantity (Bm^3)	Percent of Total
Inflows into the system from rivers and tributaries	194	100
Diversions to canals	131	68
Outflow to the sea	48	25
System losses	15	7

Source: Tarrar, 1999

Table-3: Area Affected by Waterlogging in the Indus Plain

Province	Total Command Area (Mha)	Watertable (m)	
		0-1.5	1.5-3
Punjab	9.95	0.62	1.89
Sindh and Balochistan	6.15	2.28	2.99
NWFP	0.57	0.03	0.15
Total	16.67	2.93	5.03

Source: SMO, WAPDA (1999) and MINFAL (2002)

Table-4: Area Affected by Salinity in Pakistan

Provinces	Geographical Area (Mha)	Cultivated Area (Mha)	Saline Area (Mha)		
			Cultivated	Uncultivated	Total
Punjab	20.63	12.35	1.51	1.16	2.67
Sindh	14.09	5.88	1.15	0.96	2.11
Balochistan	10.17	1.86	0.11	1.24	1.35
NWFP & FATA	34.72	2.07	0.03	0.02	0.05
Total	79.61	22.16	2.80	3.38	6.18

Source: MINFAL (2002)

Table-5: Completed Drainage Projects

Province	Projects completed	Protected Area (Mha)	Salient Features		Cost (Rs. In Billion)
Punjab and Azad Jammu & Kashmir	25	3.561	Tubewells Surface drains	15,222 No. 2,346 Km	8.558
Sindh	17	2.220	Tubewells Surface drains Tile Drains	4,788 No. 7,153 Km 13,760 ha	6.866
NWFP	7	0.046	Tubewells Surface Drains Canal Remodeling Tile drains	491 No. 901 Km 166 Km 28,906 ha	3.667
Balochistan	2	0.172	Surface Drains	2 Km	0.135
Total	51	5.999	Tubewells Surface Drains Canal Remodeling Tile drains	20,501 No 10,402 Km 166 Km 42,666 ha	19.226

Source: Tarar, 1995

Extensive efforts have been made in the past to eliminate the problem of soil-salinity and waterlogging, through sinking tubewells and the development of surface and sub-surface drainage systems, under several drainage-projects throughout the country. During 1960-1995, surface and subsurface drainage-facilities were provided in a gross area of about 6 Mha, at a cost of 19.22 billion rupees. Province-wise details of completed Salinity-Control and Reclamation Projects, upto June 1995, are given in Table-5.

2. IMPLICATIONS FOR EXISTING DRAINAGE EFFLUENT-DISPOSAL PRACTICES

The disposal of saline effluent can either be made on the surface or into the underlying aquifer. The feasible condition for discharging of the effluent into the aquifer is the availability of the transmissive aquifer underlying the impervious layer. In Pakistan, the disposal of the drainage-effluent into the aquifer-system seems environmentally unacceptable on a large scale, or on permanent long-term basis.

The disposal of effluent outside the system can only be made through disposal into sea. The Left Bank Outfall Drain (LBOD), which is the world's largest drainage engineering project, was designed to control the water-levels and dispose off the saline water into the sea. The enlargement of LBOD and its extension towards the north seems, at present, to be the only option to dispose of the drainage effluent. Similarly, construction of Right Bank Outfall Drain (RBOD) will take care of effluent from Hair Din (Pat Feeder Canal) area. However, disposal of the saline water into the sea, through LBOD and RBOD, would require heavy construction and maintenance-cost along with the resolution of social issues. The installation of high-capacity tube-wells and scavenger-wells in saline zones of Punjab and Sindh has created a detrimental effect on the environment and puts a considerable pressure on energy- consumption. The option of evaporation-ponds in SCARP-VI (Punjab) where low-lying interdunal flat valleys (interconnected and surrounded by sand dunes) are available, has been tried for disposal of drained saline water. This option also has imposed serious environmental impacts, especially rapid rise of water-table in the adjoining irrigated areas.

The existing approach to manage drainage-effluent, besides being costly and energy-expensive, has not been completely successful, due to many social and environmental implications. Therefore, other approaches, which are relatively less expensive and environment-friendly, need proper consideration. One such approach is the Sequential Biological Concentration (SBC) system. This method has been successfully used in removing salinity from the soil in saline-groundwater areas in Australia. Individual components of this system have been evaluated in Pakistan and found technically and financially viable. However, there is a need to evaluate the impact of SBC on salinity-removal from the system in Pakistan, under the local agro-climatic conditions.

3. SEQUENTIAL BIOLOGICAL CONCENTRATION SYSTEM

The SBC system completes its working in five stages (Figure 3). The first stage deals with the collection of saline groundwater, through tile drainage system, while the second and third stages concentrate on saline agriculture and saline fishery. During these stages, the drainage- effluent decreases in quantity, while the concentration of salts increases. In the fourth stage, the concentrated drainage-effluent is collected in evaporation pond and the salts are taken out of the system. Each stage of the SBC is explained in detail below:

i) **Conventional Crops**: In this stage, saline drainage-water from the tile-drainage system enters the SBC layout to irrigate a range of agricultural crops. This system can only be sustainable if a leaching fraction of 30% is maintained, which means 30% of the water applied must pass through the soil-profile to the drainage-lines beneath the system. With a 30% leaching fraction, the salinity of the root-zone will come into equilibrium with the salinity of the applied water (Figure 4). This allows the soil to sustain crop- growth, even though water of this salinity would eventually cause massive decline in yield in a poorly drained soil.

ii) **Salt-Tolerant Crops**: The leached water from the first stage is then re-used. More salt- tolerant crops can be grown, as long as the 30% leaching fraction is maintained; however the yields are not as high. The increased salinity of the applied water (1.2

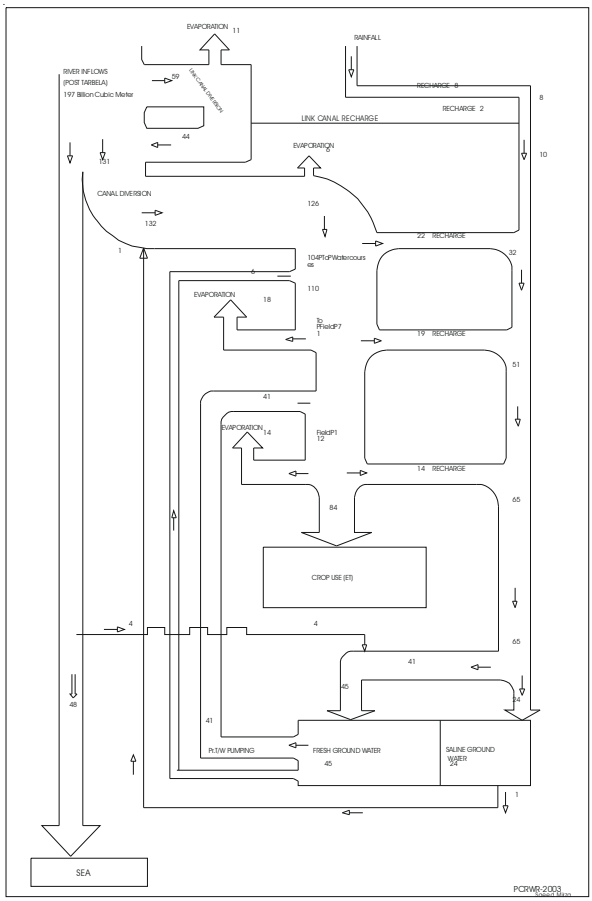

Figure - 1: Groundwaer Balance in Indus Basin

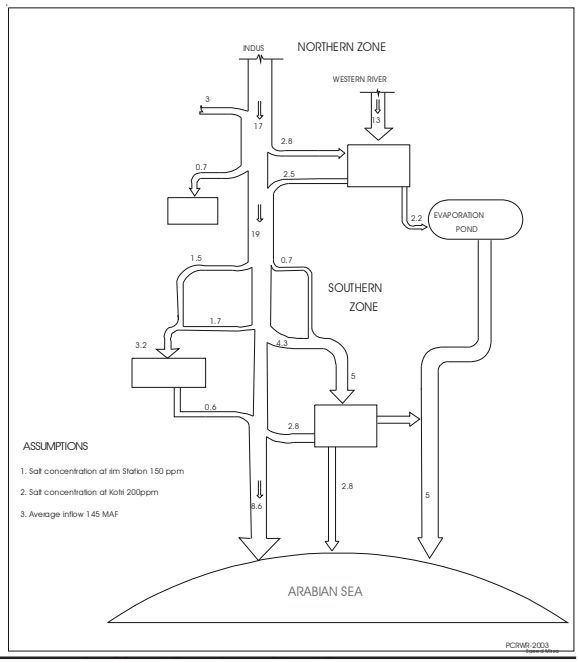

Figure - 2: Schematic Diagram of Incoming Salts and its Disposal

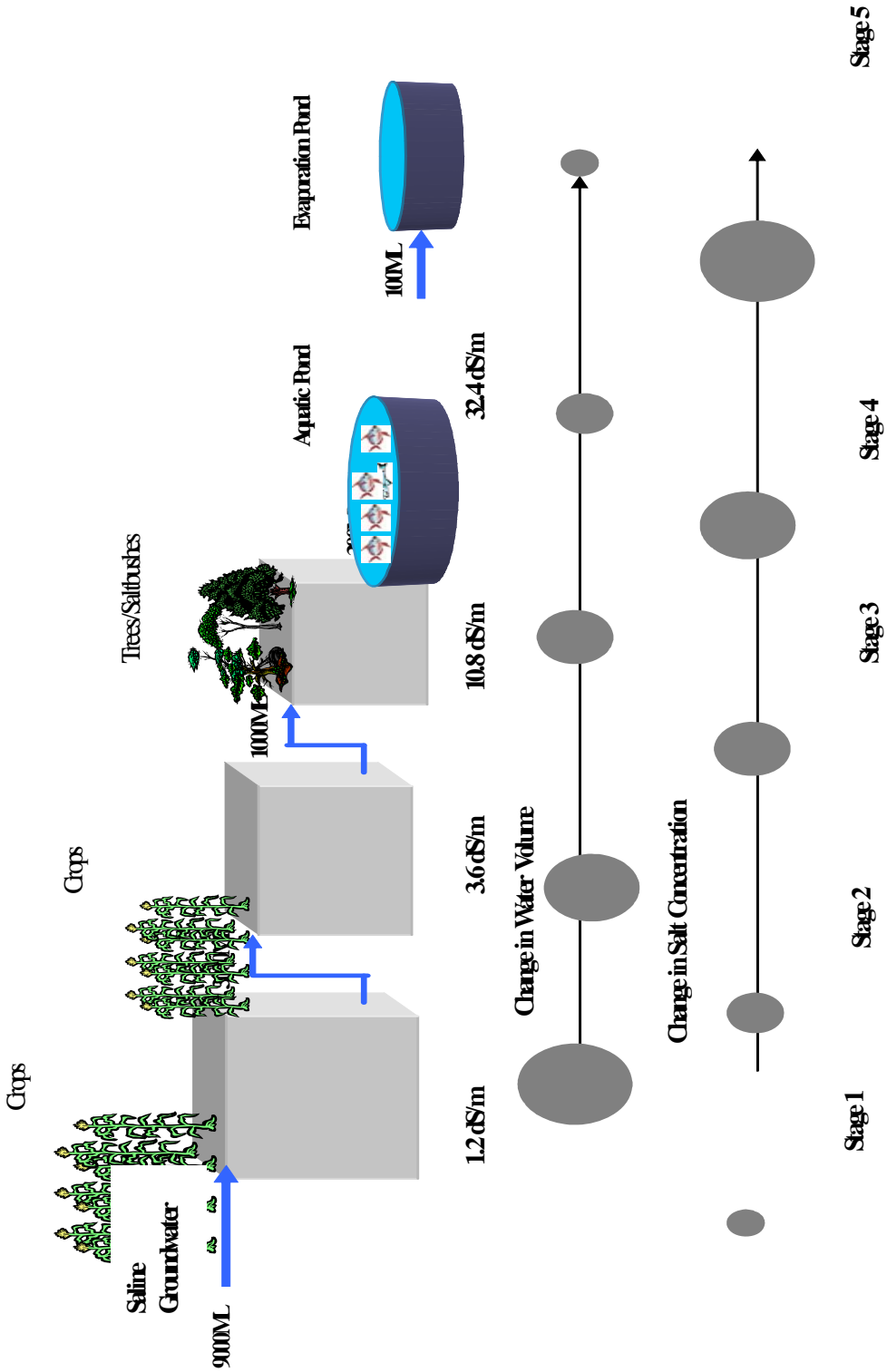

Figure - 3: Description of Sequential Biological Concentration System

dS/m at this second stage) can be expected to reduce yields by 10-20%. Drainage- effluent from this second stage can be 3.6 dS/m if the 30% leaching fraction is maintained.

iii) **Saltbushes and Trees**: At this stage, the remaining water is once again used, with reduced crop yields (Figure 5) and some of the crops that can be produced viably in the first two stages become uneconomical. In this stage, the saltbush and salt-tolerant eucalyptus is grown. Other crops cannot grow with such high-salinity water. The quantity of water was reduced from 9000 ML to 1000 ML with increase in salinity from 1.2 to 10.8 dS/m.

iv) **Saline Fishery:** At this stage, the salinity of water is increased from 1.2 to 32.4 dS/m, which is almost similar to sea water. However, water of this salinity can be used for growing fish. The water from the aquatic pond is discharged into the evaporation ponds.

v) **Evaporation Ponds:** Water of higher salinity from fish-ponds is collected in evaporation ponds. The number and size of the ponds would depend on amount of drainage-effluent. The salts from the evaporation ponds are collected and disposed off.

4. APPLICATION OF SBC IN AUSTRALIA

4.1 Saline Agriculture

The SBC method was used in northern Victoria, Australia, to reclaim about 20 ha of badly salt- affected land, using highly saline groundwater. The tile-drains were installed across the SBC site at 24m spacing, with a depth-range from 1.5 to 1.8m. The drainage effluent was used to irrigate the selected salt-tolerant tree species and grasses. This project evaluated two saltbush and 16 tree species for their growth-performance and economic potential. Two salt-tolerant grasses were also sown between the tree rows. Trees grown included *Eucalyptus cammaldulensis* (cloned Douglas Provenance), *E. spathulata*, *E. suggrandis*, *E. occidentalis*, *E. trabouti*, *Melaueca linariifolia*, *M. alternifolia* and *M. uncinata* and four Poplar species. Trees were monitored for survival, growth rate (Figure 6) and oil-yield/composition. These trees were established in the first season with fresh water (1995-96) and have received straight groundwater thereafter. During 1997-98, approximately 16 mega liters were applied to the 3 ha woodlot. An EC of 10 dS/m concentration of drainage-effluent was achieved at the last stage of SBC which amounts to the equivalent of about 100 tonnes of salt.

4.2 Saline Aqua-culture

The second aspect investigated was the saline aqua-culture. The Marine and Freshwater Resources Research Institute had conducted trials over a 3-year period. Marine species investigated included Pacific and Sydney rock oysters, King and Tiger prawns, and the fish species, Atlantic Salmon, Australian Bass, Black Bream, Greenback Flounder, Sand Whiting, and Snapper. Fresh-water species, Rainbow Trout, Silver Perch and European Carp, were also studied. Initially, all fish were stocked into 1m^3 floating cages. Fish showing the best survival and growth-rates included Salmon, Perch, Trout and Bass. The Salmon and Perch were further trailed in larger 20m^3 cages.

5. PROSPECTS OF SBC IN PAKISTAN

5.1 Saline Agro-forestry: Large area of agricultural land has been lost to cultivation, due to the twin menace of soil-salinization and waterlogging. Despite the success of previous efforts at higher costs and energy resources, sustainability of such effort is being questioned. Countries like Australia and USA have benefited from appropriate large-scale tree-plantations on saline and water-logged areas. Bio-drainage evaluation trials on saline sites, around the world, have short-listed tree species, which are both useful and salt-tolerant. Fortunately, the identified species like Eucalyptus, Acacia, etc., are being planted in the country. Thus, there are considerable opportunities for the promotion of such species to manage salinity.

5.2 Saline Aqua-culture: In Pakistan, per-capita consumption of fish has conventionally remained low, as compared to many other countries, but, still, at this low consumption-rate the pressure on fish-demand has consistently been increasing. It is a hard fact that our marine fisheries resources are already dwindling, as they are threatened with reaching maximum sustainable catch-limits. There is a need for utilization of newly created water-bodies, such as waterlogged areas. It is estimated that, out of about 6 m ha waterlogged and saline area, on about 1 million ha the waterlogged ponds have been created. In some of these waterlogged areas, water is retained

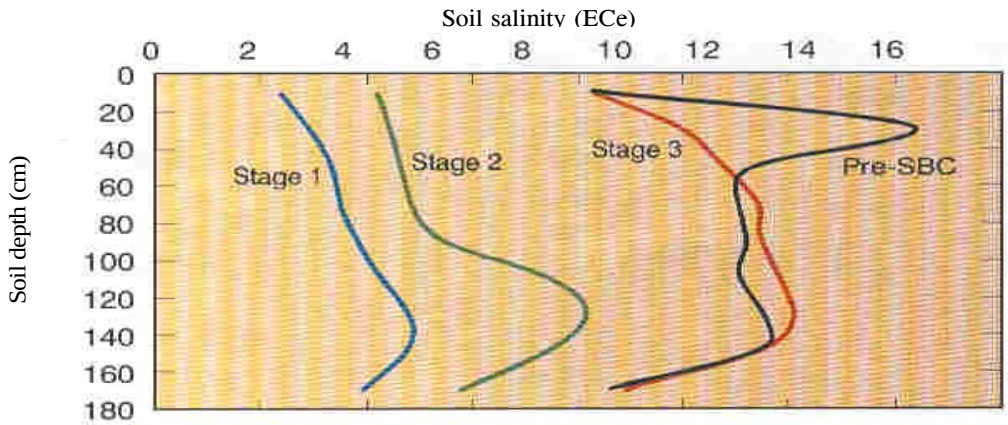

Figure - 4: Changes in Soil-Salinity Profile in the Three Stages of SBC

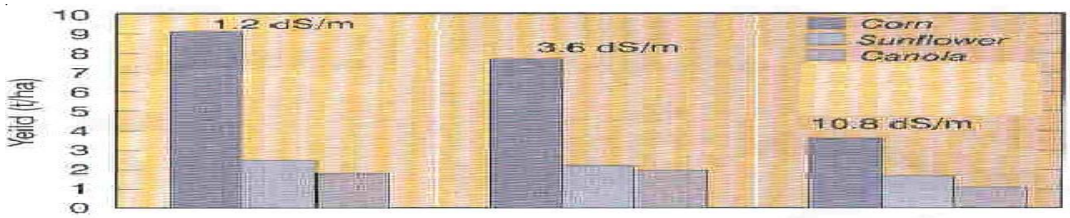

Figure - 5: Effect of Water-Salinities on Crop-Yields

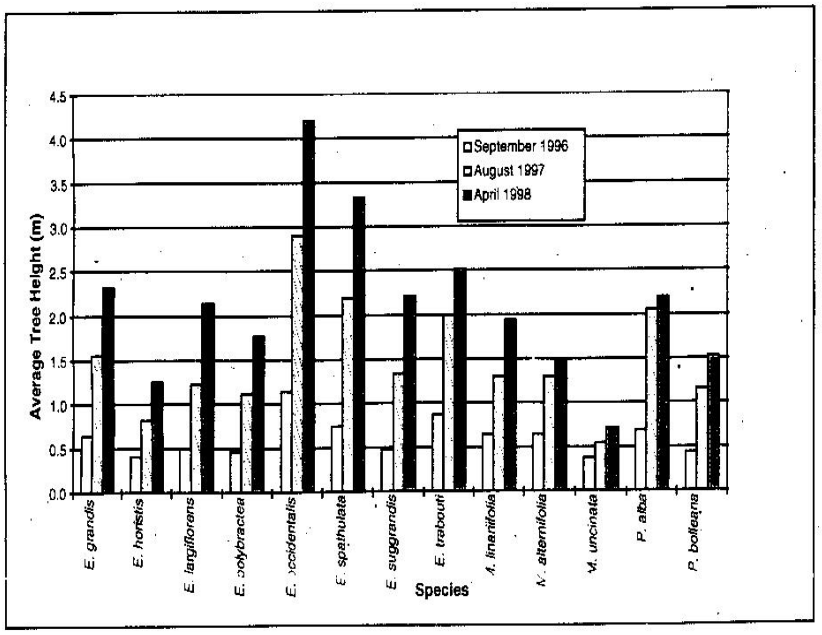

Figure - 6: Summary of Tree-Growth Data

throughout the year, while in others, the adjoining water level varies and fluctuates with the water-level of the adjoining water-bodies. To culture trash-fish in these water bodies is a major possibility for the production of fishmeal. There is an immense need for the development of vast areas under water-logging with suitable aqua-culture ponds.

The groundwater from various aquifers of irrigated plains has different levels of salinity and hampering over total production. Salinity in some waters exceeds that of seawater. There is need to introduce fish and shell-fish species tolerant to various types of saline-water environments. Several of the species presently existent in Pakistan holds good chances for the successful culture performance in saline water. However, this will largely depend upon the strength of salinity and the fluctuation in the salt-levels in the given water at the point in time. Tilapia is one option, to harness these resources. Other potent species include; basses, mullets, snake-heads and other catfishes, catla & shrimps. Crabs, particularly mud crab, could be a good choice.

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UNDERSTANDING THE PHENOMENA OF INTELLIGENT HEAT-TREATMENT

S. Khan, R. Qayyume and A. Tauqir*

Heat-treating has been a long history of development and is considered to be a mature technology. Few industries have equaled the response of the heat-treating industry to rapid changing requirement of manufacturing. Often, this response has required the development of new materials or sensors to implement existing production and control techniques. At the same time, new understanding of high-temperature reactions has been required to keep the cost of heat treatment low in response to energy shortage and "upsets" in manufacturing.

Today, major driving forces for change are the need for greater flexibility of production and more predictability of results from the heat treatment process. This has led to greater material standardization, tailoring of material composition to achieve predicted properties and application of cellular approaches to heat treatment system.

Enhanced control of processes and production allow the heat-treatment industry to contribute greatly to the modernization of manufacturing. Better sensors permit a more reliable analysis of the heat-treating parameters. Improved software enables interactive control of processes with sophisticated mathematical models, and modular hardware and software not only allow flexibility, but also provide reliability and continued enhancement of control capability as new developments in software became available. In addition, interfacing heat-treatment systems with production computers permits rapid optimization of plant productivity. These developments point to a new life-cycle curve for the heat-treatment industry.

Role of Heat Treatment in Manufacturing

Heat treatment is often considered as an art, not a science. The heat treatment system can be linked with assembly process so that common operation can be grouped together right in the production line on the factory floor. The subsequent operation after heat treatment is dependent upon the performance of heat treater. Therefore, a relationship exists between Just-in-time (JIT) and heat treatment that one can go from raw material to finish product in one continuous manufacturing flow.

Most of the time people involved with heat treatment face manufacturing deadline and production demand. Heat treater has to adopt Just-in-time (JIT) principles, which means "getting the job done right in time every time". Just-in-time (JIT) manufacturing is a fundamental prerequisite for success in today's manufacturing environment. It is not a specific technique, but rather a manufacturing philosophy and economics. The principles that form the foundation of Just-in-time (JIT) are based on common sense, and its success depends upon its ideas becoming part of manufacturing line. To accomplish this goal one must keep in mind the key aspects of heat-treating, essential for success of JIT-heat treatment[1]. The key aspects are as under:

- To know, metallurgy, what is needed to accomplish.
- To be able to predict the outcome of a heat treatment operation.
- To have repeatability built into the process.
- To use state-of-the art heat-treating equipment and methods.
- To be aware of changes to other manufacturing operations.
- Do not compromise on quality.
- Know your costs.
- Designing equipment and automation with Just-in-time (JIT) manufacturing goal in mind.

The eighth factor is important for to day's heat treater for

- Handling the job in time.
- On line reporting system.
- Relying on statical process control (SPC) techniques to assure that manufacturing flow is totally reliable.
- SPC and JIT-heat treatment makes the cost and quality of the products competitive.

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To take full advantages of the process and control the heat treaters need to emphasis on these factors to have a better quality of the products.

Intelligent Heat Treatment

When it is aimed to produce high quality product it motivates heat treater to adopt "Total Quality Management" (TQM) procedures. This comprises of computer-based management, documentation and process control system, which provide necessary information needed by the customers.

Properly implemented computerized monitoring and control procedures can help heat treaters:

- To control cost.
- Improve scheduling.
- Boost productivity.
- Optimization of equipment operations.
- High quality of the products.

With tighter process control afforded by a computer aided design, rework and rejection rates are minimized. Rework saving could be enhanced upto to 98%[2-5].

A computer-aided heat-treating system (CAHTS) has significant impact on users, as the operators are free to perform other duties. More time can be spent in fixing properly the next load, evaluating report and making strategies for heat treatment production, can alert the operator to potential problems before a crisis occurs.

Implementation of "Total Quality Management" (TQM) requires the collection and analysis of large amount of data which include process variable such as time and temperature for carburizing and/or process results such as effective case depth. Data can also include in terms of parts within specification limits vs. those parts outside specification limits, or the number of promise dates set vs. number made.

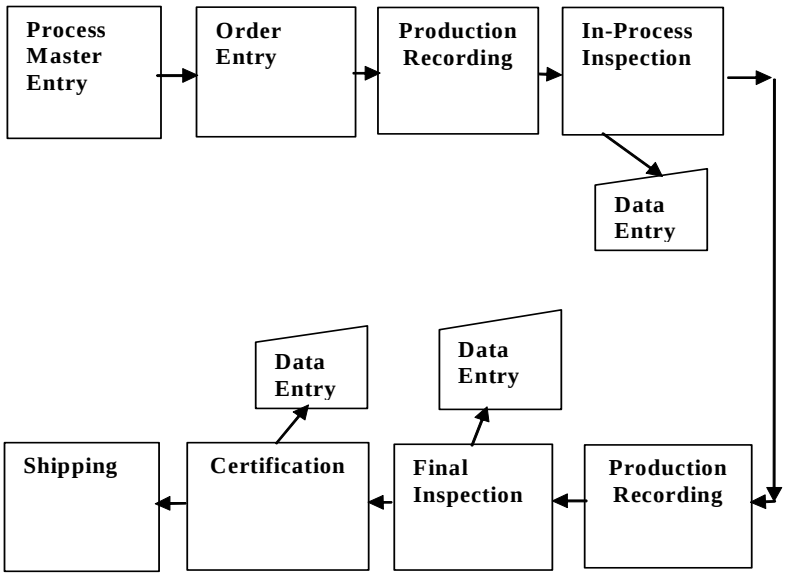
For an SQC/SPC effort to be successful and long-lived, the data collection of the system must be the mainstream information flow. Data collection must be rule rather than the exception to ensure that statical process control (SPC) soft ware will be used as a simple method of obtaining information. In addition, a convenient method of organizing data for analysis must be built into the system which structuring and formatting the way information is entered into the system, should have the flexibility and ease of retrieval. If set up properly, database will permit a single entry to be accessed many times in various ways. To accomplish this, the data must be stored with all of the possible indices and parameters that future selection of information might be based upon. This includes the shop order number, part type, heat treat process type and as-quenched hardness value.

Data collection should be implemented in a typical order-path through a heat treatment plant. Technical information on part processing first be entered on process master. Then order is generated (order entry), processing begins with system checking and recording to ensure that planned processing steps have taken place in correct sequence. In-process inspection to determine information such as if specific as-quenched hardness or case depth is required, which is the part of statical process control (SPC) data in the mainstream line information flow. Final inspection, key point in the processing route where final hardness and other mechanical properties are measured. Certification follows with a general review of all processing and the preparation of documents to confirm that heat treatment meets customer's criteria.

In general Just-in-time (JIT) heat treatment, tighter process control, on line data collection all are the part of "Total Quality Management" (TQM), and once these have been established properly, it means-doing intelligent heat treatment.

Computer Controlled Heat Treating Problems

In the past, the computer control system technology was not available, the heat treaters were not able to measure completely and accurately all of the process variables that can affect materials during heat treatment. However, recent advancements in control-system designs, sensor technology, digital communications have made it possible to develop a computer control system that enables heat treater to meet both process-control and cost reporting requirements.



On line Data Collection Flow Chart is shown in Figure 1 [6,7]

Figure - 1: Shows the Flow Chart Block Diagram. Data Collection should follow the Typical Order Path through a Heat-Treating Plan

The Model so Developed Shown in Figure 2

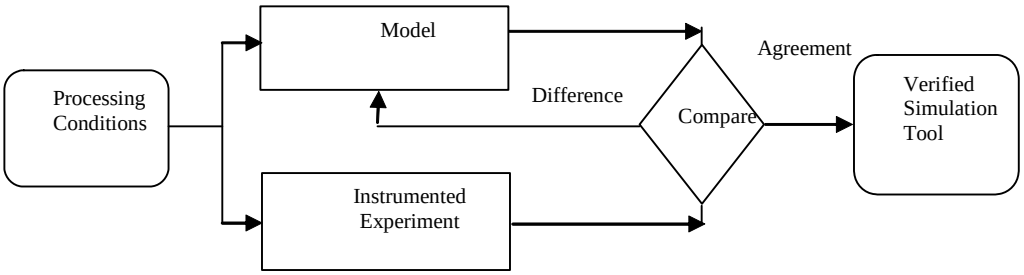


Figure – 2(a): The Finite-Element Model of a Heat-Treating Process can be verified by Comparing Key Parameters with those from an Instrumented Experiment

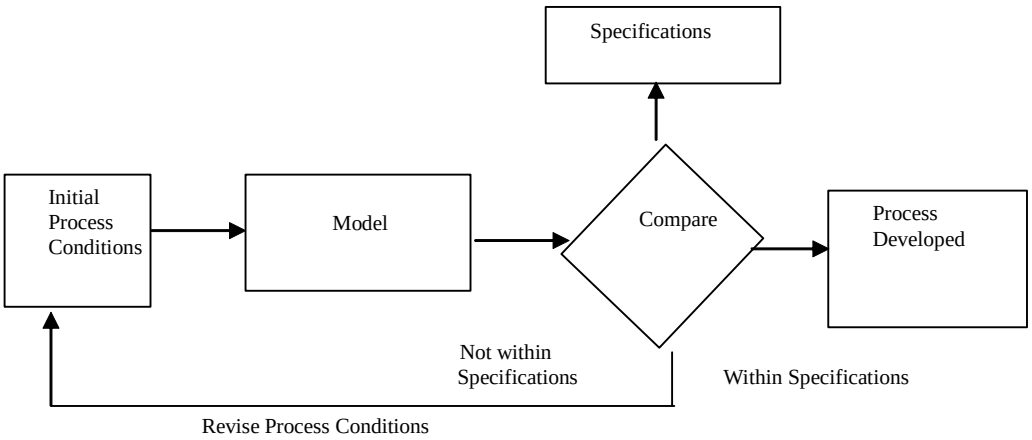


Figure – 2(b): The Verified Finite-Element Model of a Heat-Treating Process can be used to Improve Quality of the Product.

Understanding the Phenomena of Intelligent Heat-Treatment

The recently developed modeling tool encompasses the capability to analytically determine the behaviour of steel components during heat treatment. Once the process parameters for the type of quenching and the steels properties have been determine, this analysis is used to predict the effect of process changes, such as part shape, material specification, and quench conditions on final products[6, 8].

was given trial run on computer, rather than costly trial-and-error experimentation on the shop floor. The improved and optimized process can help to:

- Reduce scrap or rework rate.
- Reduce or eliminate final grinding of parts to meet specifications.
- Reduce trial and error in developing process parameters for new parts.
- Allow tighter tolerances to be achieved via better control of heat-treating process.

This technique is used for virtually all of the major heat-treating and surface-modification process to produce critical parts. The processes include carburizing, nitriding, hardening, tempering, annealing and stress reliving. In addition, it is also applied to an extremely broad range of part shapes and materials. To date, most of the efforts have been on parts made of various low-alloy steels, such as AISI 4140, 4335 and 4340 etc. However, this technique can also be applied to other metals and alloys. Specific applications are hardening of gun barrels, heat treatment of fasteners and heat-treating of high performance gears. For each application, heat transfer data, numerical data and process parameters are input into a numerical model. The model is then used to determine distortion or residual stresses.

- **Gas Carburizing By Computer**

The gas-carburizing process provides the best illustration of these developments theoritical explanations for the gas reaction enable engineers to predict and control the carbon gradient in alloy steels[9-12]. This understanding enables design engineers to produce fatigue-resistance parts at lower material cost.

Precise control of carbon profile on the carburized parts is now possible with the advent of this control technology (numerical model). The key control gases (CO_2, CO & other gases) could not be possible to measure accurately and reliably in the parts in industrial heat-treating furnaces. Today, however, infrared analyzers permit continuous analysis of CO_2, CO and other gases. In addition, the introduction of the solid-electrolyte oxygen sensor, which is based on the changes in electrical properties of zirconia in the presence of minute amount of oxygen, permits rapid determination of sensitive carbon-reactive variables. These developments led directly to the application of mathematical model to the carburizing process.

Computerized systems are applied to control the gas-carburizing process, on line monitoring of carbon diffusion into the parts. These systems not only regulate the gas carbon profile but also calculate carbon mass transfer and diffusion. Fig. 3a demonstrates the carbon profile illustrates by comparing the target specified and actual profile during the process, and Fig. 3b produces the carbon profile of steel gears that agree with values predicted by the computer simulation. Carburized parts having this profile provide high fatigue resistance and reproducibility, especially on surfaces requiring grinding after treatment.

This technique is reliable in obtaining the surface carbon concentration and case depth needed to achieve a given carbon content.

Heat Treatment Industry of The Future

The heat treatment industry is recognized as vital part of the manufacturing operation, and is characterized by long-term partnerships with customers, supplier universities and government. To keep a balance relationship with these agencies heat treaters will have to look upon[3]:

- What technological advances will the heat treaters to work with?

- How the technological advances enable heat treaters to meet customers demand while keeping their products competitive and profitable?

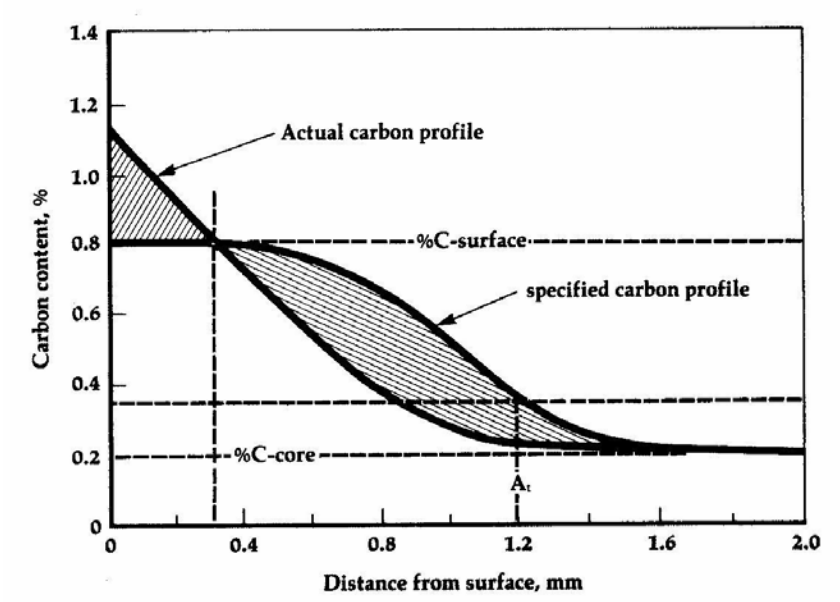


Figure - 3(a): Total Carbon-Profile Control may be Illustrated by Comparing the Target (Specified) and Actual Profiles during the Process. The Shaded Areas Represent the difference between the Integral of two Profiles

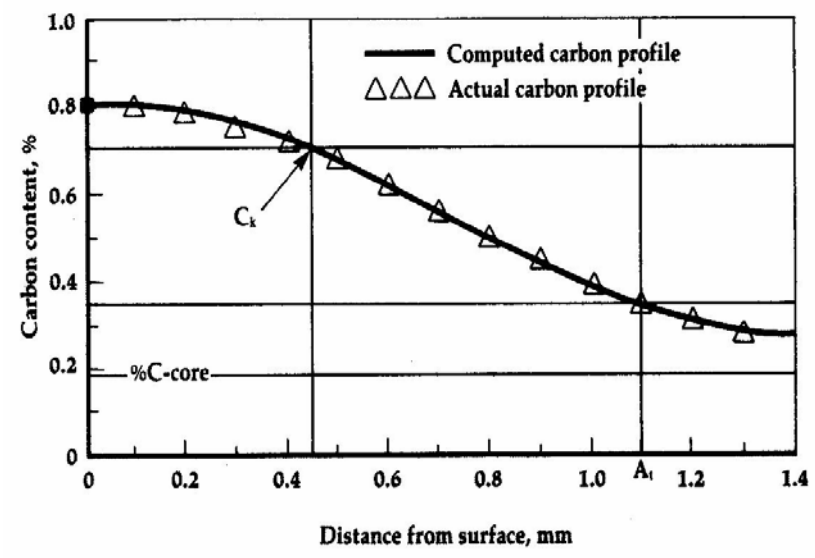


Figure – 3(b): Carbon Profiles that agree with Values Predicted by Computer Simulation, Shown for Steel Gears

A technological road map, describing the specific strategies, needed to be developed and implemented for "A Vision of a Heat Treatment Industry Of The Future".

The heat treaters should have to adopt following strategies for application of advanced technologies:

• **Global Standards**-have to be established for materials, heat treated parts, safety of the work force and environmental friendliness. Standards also to be established for electronic communications enabling quick and reliable transmission of information between the heat treaters and customers.

• **Operations Of Captive Facilities-**are value-added profit center characterized by advanced technology, well trained workers and low operation cost. Large captive facilities have decentralized their heat-treating operation and may include a heat-treating system on each production line. Some of these "in-line" systems are operated by commercial heat treaters on a contract basis. In other capacities, separate heat treating operations are carried out by commercial heat treaters.

In both captive and commercial facilities, higher production reduced energy usage and improved environmental performance has been achieved by means of increased throughput and focused energy processes.

• **Environmental Impact**-of heat-treating should be reduced to zero; completely self-contained, closed loop systems are standards. Quenchant are used should be non-polluting and nonflammable. Emission of chemicals, heat and gases should be eliminated.

• **Government Relationship**-should play their role in terms of tax incentives, availability of funds for industrial growth and modernization, encouragement of bank loans for implementation of advanced technologies.

• **Heat Treating Employees**-means giving some benefits to the heat-treating personnel by providing them safe, clean and comfortable environment. Organizing short courses and training program in collaboration with universities/other educational institutions. Heat-treating companies should recognize that progress is readily needed with educated, confident and flexible people.

• **Materials And Process**-complete technical know-how should be obtained for the part to be heat-treated.

Industry Challenges

The heat-treating industry faces technological, government, profitability, customers, structural and workforce challenges to achieve the set goal.

• **In The Technology Area-**research priorities include developing more efficient furnaces, longer-lasting material for furnace hardware, more precise control of processes, and improved cooling medias. Achievements of these research goals can be accelerated through co-operative projects with federal agencies. Such program would involve industry, technical societies and universities.

• **The Work Force Of The Future**-is another major challenge. The industry must attract people who have the potential to learn and train them to become skillful employees who will hold good jobs in a clean and safe environment. Heat treaters should promote friendly relation with technical societies, trade associations, universities and community colleges for the education of engineers and technicians.

• **Government Regulations & Product Liability-** must be mitigated if heat-treating is desired to be prospersed. Collaboration replaces confrontation to help the industry develop technologies that ensure workers safety and environmental friendliness. Reforms are required so that new products can be developed without the fear of frivolous low suits. This is proper way to reduce the expenses and the industry can be globally competitive.

• **Profitability**-must be improved in order to attract the capital that drives technology advances. This will follow from aggressive research and development program funded by the industry in collaboration with universities and national laboratories.

• **Customer/Industry Relationships-**must be established right from product design phase. The

industry must take active part in programs like; helping and providing guideline for selection of materials that low in cost yet develop advanced properties after heat treatment.

• **The Structure Of The Industry**-today's manufacturers is out sourcing parts of the manufacturing process. A possible scenario for heat-treating could be that of specialized segment in the production line. Such as "heat-treating module" could be the complete responsibility of independent heat treaters.

CONCLUSION

• Design of heat-treating processes can be improved and made more efficient through numerical simulation.

• Computer-aided control offers heat treaters the capability to meet the most stringent customer's material-specification requirements.

• Better sensors, improved computer software and adaptive process control permit optimization of heat-treat production.

• With tighter process control, rework and scrap are reduced.

• Computer controls enable workers to work in a clean, comfortable environment. In order to efficiently operate and maintain this advanced equipment, workers will be among the most technologically capable in manufacturing.

• The industry faces significant challenges in areas of training and partnerships. Lack of knowledge about industry by young people may result in a diminishing pool of future work.

• The importance of close working relationship with customers and suppliers must be recognized if heat treaters are to improve the profitability of all product manufacturing.

• Effective solution of the challenges requires collaborative efforts between industry, technical societies, government, and academia.

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BIO-SCIENCES AND AGRICULTURE

GRAZING FOURWING SALTBUSH (ATRIPLEX CANESCENS) UNDER DIFFERENT SUPPLEMENTAL FEEDING-REGIMES IN HIGHLAND BALOCHISTAN

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ABSTRACT

A grazing trial on fourwing saltbush pastures was conducted during summer and early fall of 1993 with three different grazing treatments (fourwing saltbush grazing with no supplementation, fourwing saltbush grazing plus 200 g of wheat-straw/head/day and fourwing saltbush grazing plus 500 g wheat-straw/head/day) to investigate the grazing potential of fourwing saltbush pasture and devise management-systems for efficient utilization by sheep. Eighteen Harnai yearling rams, weighing 23±0.95 kg were used in the study in a randomized complete block design, divided into three groups, and the treatments were allotted to each group randomly. All the animals were grazed in the allotted plots of saltbush pastures in two grazing sessions; morning and evening.

The grazing trial lasted for 15 weeks from mid-June to the end of September. At the end of the grazing study, animals attained varying live weight gains (6.4%, 8% and 10%, respectively) in the three grazing treatments. Animals in the saltbush grazing treatment with no supplementation started losing weight after 10 weeks of the grazing period, while animals in the grazing treatments supplemented with 200 g wheat-straw/head/day maintained their body weights at the end of the study. The yearling rams in the grazing treatment offered 500 g wheat straw/head/day gained weight till the end of the study-period. Combining wheat straw with fourwing saltbush diet can thus offer a suitable grazing-regime for utilizing saltbush pastures during summer and fall seasons.

Key words: Balochistan, fourwing saltbush, grazing, intake, sheep.

INTRODUCTION

Sheep and goat-rearing is the main use of rangelands in highland Balochistan, and about 80% of the rural population live from the sale of small ruminants and their products (FAO, 1983). Out of the total area (34.7m ha) of Balochistan, 21 million ha or 60% is used for grazing (FAO, 1983). According to the latest census carried out in 1996, approximately 20.24 million sheep and goats have been reported in Balochistan (GOB, 1996). Rangelands are the major feed-source for these animals and about 90% of the feed-requirements are met from rangelands (FAO, 1983). However, due to high grazing-pressure and human disturbances, these ranges are unable to fulfil the feed-requirements of small ruminants, particularly during fall and winter seasons (Mirza et al., 1995). As a result of this feed shortage, animal-productivity is severely affected in the region (Akbar et al., 1990). To overcome this problem, research conducted at Arid Zone Research Centre has identified and evaluated various exotic fodder-shrubs, which are adapted under the prevailing environmental conditions (Mirza, 1995).

Atriplex canescens (Pursh) Nutt., commonly known as fourwing saltbush, is a perennial halophytic exotic shrub, native to Western United States. It has shown potential as a promising fodder-shrub in areas having 250-300 mm annual rainfall in highland Balochistan (Mirza, 1995). The area has a typical continental Mediterranean climate, with cold winter and dry summer seasons (Kidd et al. 1988). Fourwing saltbush is extremely drought and cold-tolerant and provides high-quality browse, especially during summer and autumn months (Mirza, 1995; Thomson et al., 1997). This shrub produces leaves and twigs round the year. Fourwing saltbush can withstand moderate to heavy grazing-pressure (Rumbaugh et al., 1982), but, without suitable grazing-management, sustained production is not maintained (Jefferies and Pitman, 1986). Utilization of saltbush by animals is generally recommended after 18 to 24 months of growth (Ueckert, 1985). The crude-protein content in leaves of fourwing saltbush has been reported from 12 to 15 % during mid winter (Thomson et al., 1997).

It has been suggested that one acre of fourwing saltbush might provide the supplemental protein

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requirements for 0.5 to 1 animal unit during a 90-day period (Ueckert, 1985). Like other halophytes, fourwing saltbush has low energy-values because of high ash-contents. The energy-values are reported to cover only maintenance requirements of sheep, if they consume 1.2-1.5 kg DM/d (Le Houerou, 1992). But nutritionally, saltbush species contain high nitrogen-values, which have been reported to be as high as 2.5-3.5 % DM , i.e., 16-20% of crude protein (Le Houerou et al., 1982, 1983; Hassan et al., 1979). The digestibility of dry matter and of organic matter has been reported to be around 60% and 50%, respectively (Le Houerou et al., 1983). The digestibility of nitrogen has been reported to be around 65%, but the retention of nitrogen is only 55% (Benjamin et al., 1992). Atriplex, supplemented with grazing of native ranges, resulted in animal weight-gains of around 80 g/h/d (Le Houerou et al., 1983). Atriplex forage consumption, in addition to stubble or wheat-straw consumption, could lead to a well balanced ration and fulfil the nutritional requirements of animals in a productive grazing system (Le Houerou et al., 1991).

Various pen-feeding studies have already been conducted on fourwing saltbush, to investigate its potential as a forage-crop with other supplements (Thomson *et al.,* 1997). However, very little information is available on grazing-behaviour and grazing-management of this species. Therefore, the present study is conducted to investigate the grazing-potential of fourwing saltbush pasture and devise management-systems for efficient utilization of these pastures by sheep.

MATERIALS AND METHODS

The grazing trial on fourwing saltbush pastures was conducted during summer and early fall of 1993. Groups of three yearling rams of Harnai breed, weighing (23 ± 0.95 kg) were used, each in three different grazing-treatments viz; fourwing saltbush grazing with no supplementation (FWSB alone), fourwing saltbush grazing plus 200 g of wheat-straw/head/day (FWSB+200g WS) and fourwing saltbush grazing plus 500 g wheat-straw/head/day (FWSB+500g WS). There were two replications for each treatment. Two adjacent blocks (replicates) of sizes 35 x 152 m and 42 x 133 m, respectively, planted with fourwing saltbush shrubs at 2 x 2 m spacing during early summer of 1987 at Arid Zone Research Institute (AZRI), were used. At the start of the study, all leaves and young twigs from seven randomly selected plants in each plot were removed, weighed, and dried at 70°C for 24 hours, and multiplied by the total number of plants in each plot to determine DM forage biomass of fourwing saltbush available at the start of the study. About 1000, 747 and 687 kg DM/ha of fourwing saltbush was available at the start of the study in the plots assigned to the yearling rams for the three grazing treatments, respectively. Five randomly selected plants in each plot were protected by 1.5 x 1.5 m cages and the biomass of leaves was measured at the end of the study, in order to measure the off-take of saltbush leaves per head of sheep. The amount of saltbush consumed by sheep was measured at the end of the grazing-trial by the estimation of forage on caged (ungrazed) and grazed plants in each plot. The amount of forage contributed by understory (grasses and forbs) in each plot was also measured at the start of the trial, by harvesting above-ground biomass inside the 5, 1m^2 quadrats in each plot.

The two blocks were divided into three equal plots; each plot was grazed by three lambs from June 15 to September 29, 1993. Stocking-rate, calculated on the basis of saltbush forage biomass, was about 16 rams/ha/15 weeks. The yearling rams were grazed from 800-1200 h. and then 1700-1900 h. daily for 15 weeks. Known quantities of wheat-straw were offered to the groups in the two treatments (grazing plus 200g and 500g wheat straw/head/d, respectively) after the first grazing session i.e., at noon. The refused wheat-straw was measured the next morning before removing animals for grazing, to determine daily wheat-straw intake (g) for each group. Each group was offered a known amount of water throughout the day and night, and the daily water-intake in litres for each group was measured. Sheep were weighed at the start of the trial, then once a week in the morning until the trial ended. The weekly data on changes in body-weight (kg) and water-consumption (litres) by yearling rams were analysed, by using analysis of variance in a Randomized Complete Block Design.

RESULTS

Weekly body-weight change (kg) and daily water-intake (litres) of Harani yearling rams in different grazing regimes are shown in Fig 1 and Table 1. No

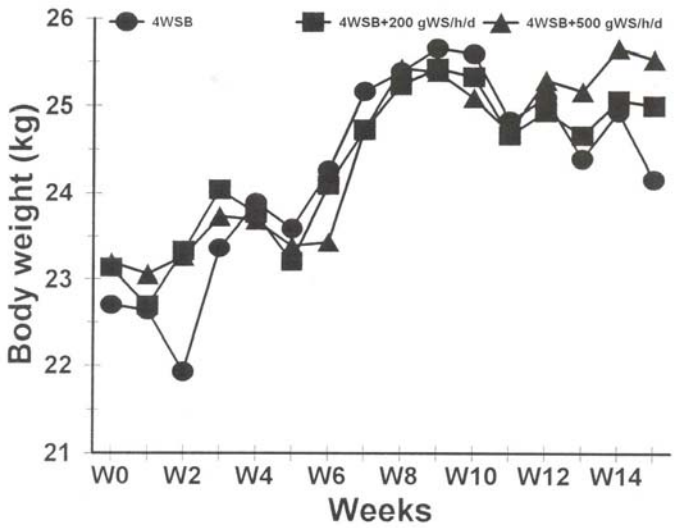

Figure - 1: Weekly body-weight changes in yearling Harani rams, starting June 16 (week 0) to September 29 (week 15), with three different grazing-treatments (4wsb grazing with no supplementation, 4wsb+200 gws/h/d and 4wsb+500 gws/h/d). Weekly body-weight changes did not significantly (P>0.05) differ among the three grazing treatments

significant (P>0.05) differences was observed in weekly body-weight change and water consumption among the three treatments. The daily intake of fourwing saltbush leaves from mid June to end of September by 23 kg rams in the three treatments was 466, 390 and 356 g DM and of chopped wheat-straw 0, 176, and 371 g DM, and the daily gains were 14, 18 and 22 g, respectively (Table 1). The understory vegetation (dry annual grasses and forbs) also contributed towards the total intake by the animals. About 36, 41 and 45 kg DM was available from dry annual and perennial grasses in the grazing plots. Animals consumed all the understory forage by the end of the trial. The total dry-matter intake by yearling rams (saltbush forage, wheat straw and understory forage) was 581, 698, and 871 g DM/head/day, respectively (Table 1).

During the grazing-trial, the total dry-matter of saltbush leaves and young twigs on offer was 1000 kg/ha, and the animals consumed almost 90% of the available forage by the end of the trial. The average daily consumption of saltbush forage in this trial was 466 g/head/day, while that of understory grasses was 114 g/head/day in the saltbush grazing treatment without supplementation. At this rate of consumption, the grazing trial established a stocking-rate of fourwing saltbush pasture as 15 yearling rams/ha for 15 weeks or 4.25 rams/ha/year.

The weight-gain data over 15 weeks period show an increase in weights by yearling rams in all treatments, with maximum cumulative increase (2.3 kg) in the treatment; FWSB+500 g wheat straw, followed by 1.9 and 1.5 kg increase in the treatments; FWSB+200g wheat straw and FWSB alone, respectively (Table 1). Animals in all three grazing-treatments showed maximum increase in their body weights, as well as average daily gain, during 10th week of grazing period; while animals in the saltbush grazing treatment without supplementation started losing weight, the animals in the other two treatments supplemented with wheat straw maintained their body weights during the next five weeks of grazing trial.

Off-take of saltbush leaves and twigs by the animals grazing on saltbush pasture alone was higher than that in the other two treatments. Animals consumed 49,41 and 37.4 kg/head of fourwing saltbush leaves and twigs during the study-period in the three treatments, respectively (Table-1). The water-consumption also did not differ significantly (P>0.05)

Table – 1: Grazing days, live weights (mean◆SE) and average daily gains of sheep, off-take (mean◆SE) of saltbush forage, and intakes of saltbush leaves, wheat straw and water (mean◆SE) in three different feeding regimes

	Saltbush grazing alone	Saltbush grazing+ 200g WS/head/d	Saltbush grazing+ 500gWS/head/d
Grazing days	105	105	105
Initial live weight (kg)	22.7 ± 1.68	23.1 ± 1.87	23.2 ± 1.73
At week 10			
Live weight (kg)	25.7 ± 1.63	25.4 ± 2.18	25.4 ± 1.49
Average daily gain (g)	48.0	36.0	35.0
At week 15			
Final live weight (kg)	24.2 ± 1.53	25.0 ± 2.30	25.5 ± 1.53
Cumulative weight gain (kg)	1.5	1.9	2.3
Average daily gain (g)	14.0	18.0	22.0
Off-take saltbush (kg/head)			
Initial Biomass	54.0 ± 7.50	45.0 ± 8.33	42.0 ± 3.15
Final Biomass	5.1 ± 1.95	4.0 ± 0.06	4.6 ± 0.07
Off-take	49.0	41.0	37.4
Intakes (g DM/hd/d)			
Saltbush leaves	466	390	356
Straw	-	176	371
Grasses+ forbs	115	132	144
Total	581	698	871
Water Intake (l/hd/day)	3.7 ± 0.17	3.5 ± 0.15	3.7 ± 0.17

among the three grazing treatments. Animals consumed an average of 3.7, 3.5 and 3.7 litres of water per head/day in the three treatments, respectively (Table-1).

DISCUSSION

Though the yearling rams gained weight in all grazing-treatments during the 15 weeks of grazing-trial, maximum increase (10%) of the body-weight was achieved in FWSB+500g wheat-straw followed by 8% and 6.6% increase in the treatments: FWSB+200 g wheat straw and FWSB grazing alone, respectively. Animals in all grazing treatments attained maximum weight gain during the 10th week of the study period. The performance of animals in terms of body-weight gain after week 10 of grazing could have been affected due to less availability and intake of leafy foliage of saltbush towards the end of the study period. There could have been apparent decrease in forage-quality, as animals consumed more and more fibrous saltbush forage (twigs and small stems) towards the end of the grazing trial (Atiq-ur-Rehman et al, 1990b).

The results of this study suggest that, during fall and winter, when the native range vegetation goes dormant, and the animals start losing weight (Akbar et al., 1990, Atiq-ur-Rehman, et al., 1990a), grazing saltbush pastures could offer modest live-weight gains, especially when grazing is supplemented with 500g wheat straw/head/d. Rasool et al., (1993) suggested that inclusion of fourwing saltbush, up to 0.30% of the total diet, enhances straw-intake. In another study, which compared saltbush pasture grazing with native range grazing, range grazing with lucern hay and range grazing with barley grain, six months old lambs weighing about 12.5 kg gained an average of 6% of their body-weight by grazing saltbush pasture as their

sole diet over 10 weeks period. The study concluded that, under fourwing saltbush grazing alone, lambs not only maintain their body-weight but also gain some weight during early winter (Atiq-ur-Rehman et al., 1990b). Another study concluded that saltbush harvested at the beginning of winter season has a feeding-value below the maintenance requirement of sheep. This study concluded that sheep browsing on saltbush pasture, late in the season, would need to be fed wheat-straw for maintenance (AZRI/ICARDA, 1992).

The off-take value of saltbush foliage in the three grazing-treatments did not differ much. Animals in all grazing treatments consumed about 90% of the saltbush foliage on offer by the end of the study. This shows that established saltbush stands, in highland Balochistan of 1000 kg foliage DM/ha, can allow an off-take up to 750-900 kg DM of saltbush foliage at medium (75%) to heavy (90%) grazing-pressure during summer and fall period. At these off-take rates, saltbush pastures can be grazed at a stocking rate of 12-15 yearling rams/ha/15 weeks during summer and fall seasons.

The wheat straw intake by the animals in the two treatments; grazing saltbush+ 200 and 500 g wheat straw/head/d was 176 and 372 g/head/d, respectively. This shows that the animals offered 200g wheat straw/ head/d consumed 88% of the straw and the refusal in this case was the hard stem portion of straw rejected by the animals. In the treatment FWSB+500g wheat straw/head/d, animals consumed 75% of the wheat straw, which shows that the animals grazing saltbush forage during summer and fall seasons should be supplemented with at least 400g wheat straw/head/d in order to attain modest weight gains.

Ruminants grazing on saltbush diets may increase the water intake due to ingestion of large quantities of sodium and potassium chloride (Le Houerou, 1995). However, in this study the water intake was not much different in the three grazing treatments during the entire grazing period. Rasool et al., 1995, also reported low amounts of water intake by sheep fed fourwing saltbush leaves during December and related this to low salt contents in FWSB leaves. Different results have been reported for water intake on fourwing saltbush grazing alone and in combination with other supplementals (Thomson et al., 1997). These differences may be due to body weight, dry matter consumed, ash content of the diet, and ambient temperature.

Sheep grazing saltbush range have to avoid grazing during the period of hot weather to reduce stresses of a combination of heat and high salt ingestion and reduce water-demands significantly (ACSAD, 1987). The grazing of animals on saltbush pastures in the morning and evening may reduce the heat stress during summer season and extra water intake helps to excrete sodium and potassium chloride.

CONCLUSIONS

Browsing shrubs in forage reserves is considered to be the appropriate way to utilize saltbush pastures, though farmers can also cut and carry these shrubs to use as feed and get some fuelwood. The results of this study indicate that the sheep can maintain their body-weights if fourwing saltbush pastures are grazed during summer/early autumn, when growth of the shrubs is maximum and the nutritional quality is adequate. However, the results also indicate that modest weight-gains can also be achieved if supplements are offered with fourwing saltbush diet. In this case, the addition of wheat-straw to the diet of saltbush forage had shown better performance in yearling rams over a period of 15 weeks, as compared to grazing saltbush pasture alone. Combining wheat-straw with fourwing saltbush diet can offer a suitable grazing regime for utilizing saltbush pastures during summer and fall seasons. This system has an advantage over grazing saltbush pastures alone, in meeting both energy and protein requirements of sheep and allowing more persistency of the shrubs, as these are not subjected to heavy grazing when supplemented with alternate feed. These results are in agreement with those on penned sheep: that modest gains in live-weight can be expected if supplements are offered with fourwing saltbush diet (Thomson et al., 1997).

Currently, it is not known how farmers will manage their saltbush reserves and, therefore, it is important to expand the area and number of reserves on Government and private farms, so that these can be grazed by farmers' animals. Meanwhile, more detailed grazing-studies are needed, which will give researchers the information necessary to advise farmers on grazing-regimes that allow good off-take from saltbush reserves, without jeopardizing the persistency of the plants.

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RESPONSE OF RICE TO ZINC-APPLICATION AND DIFFERENT N-SOURCES IN CALCAREOUS SOIL

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ABSTRACT

Widespread Zn deficiency in soil causes serious yield-reduction in rice. Use of zinc (Zn) alongwith nitrogenous fertilizers does improve crop-yield and fertilizer-use efficiency. Therefore, a pot experiment using four N fertilizers viz., urea, ammonium sulfate, calcium ammonium nitrate (CAN) and ammonium nitrate (AN) each @ 100 kg/ha, with and without Zn, was conducted. Paddy and straw-yield and paddy-to-straw ratio of rice increased significantly by the application of fertilizer N, accompanying zinc in all treatments. Paddy and straw-yield increased by 25 and 14% in ammonium sulfate - Zn , 28 and 13% in urea –Zn, 19 and 9% with CAN –Zn and 12 and 9% with AN - Zn, over control, respectively.

Ammonium sulfate by reducing soil pH enhanced growth and paddy yield more than other sources. All N sources used in the absence of zinc produced low paddy and straw yield. A significant increase in paddy-to-straw ratio, tissue nitrogen and zinc concentration and their uptake in rice were achieved in case of ammonium sulfate and urea. Application of zinc alongwith N had synergistic effect on N and Zn uptake in rice.

key words: Oryza sativa, nitrogen, zinc, urea.

INTRODUCTION

Rice Response to Zinc and Nitrogen

Zinc (Zn) deficiency, the most common nutrient disorder constraining rice-productivity, world wide, is effectively controlled by field-application of zinc sulfate ($ZnSO_4$) (Rashid, 1996). Due to clayey, alkaline and calcareous nature of soils in Pakistan (Tahir *et. al*., 1991), fertilizer Zn is mainly adsorbed by soil and very little is available and recovered by plants. Zinc, being an expensive fertilizer must, therefore, be applied in a way that may enhance its availability as well as efficiency in soils. Nitrogenous fertilizers are commonly used for crop-production in Pakistan. Use of nitrogen from different sources may influence the efficiency of Zn (Sing *et al*., 1995; Tahir and Kausar, 1994). Application of acid-forming N-fertilizer, like ammonium sulfate, by reducing soil pH causes enhanced availability of Zn to plants. In contradiction to the positive effect, several workers (Forno *et al*., 1975, Halder and Mandal, 1979) found depressing effect of urea on Zn uptake due to interference of HCO_3 ions in plant. The soils of Pakistan, being situated in arid and semiarid regions, are deficient in Zn (Rashid *et. al*., 1999). Liberal application of N on these soils may further aggravate Zn-deficiency, due to enhanced Zn uptake causing substantial yield-losses in the long run (Rashid, 1996). Therefore, this study was aimed at studying the response of rice to Zn application and different N-sources.

MATERIALS AND METHODS

A pot experiment to study the effect of N-sources, with and without Zn, on rice-growth was conducted on sandy clay loam soil. Bulk soil sample from 0-15 cm depth was collected from experimental field-area, with its characteristics (Table 1). After soil preparation, it was filled in glazed pots @ 10 kg per pot. The various nitrogen sources used were : urea, ammonium sulfate, calcium ammonium nitrate (CAN) and ammonium nitrate (AN). Nitrogen was applied @ 100 kg/ha in two splits(half at transplanting and half at booting stage). Basal dose of P and K was applied each @ 50 kg/ha as single super-phosphate and potassium sulfate, before transplanting the nursery plants of rice variety IR-6. Application of $ZnSO_4$ @ 10 kg/ha was added in the following sequence:

- T_1 100 kg N/ha as urea, with no zinc.
- T_2 100 kg N/ha as urea, with 10 kg $ZnSO_4$/ha.
- T_3 100 kg N/ha as ammonium sulfate, with no zinc.
- T_4 100 kg N/ha as ammonium sulfate, with 10 kg $ZnSO_4$/ha.
- T_5 100 kg N/ha as calcium ammonium nitrate (CAN), with no zinc.
- T_6 100 kg N/ha as calcium ammonium nitrate (CAN), with 10 kg $ZnSO_4$/ha
- T_7 100 kg N/ha as ammonium nitrate (AN), with no zinc.

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Table – 1: Physico-chemical properties of the soil

Property	Value
Texture	Sandy clay loam
pH_s	8.0
EC_e (dS/m)	1.7
OM (%)	0.44
Olsen P (mg/kg)	6.22
DTPA-Zn (mg/kg)	1.4
Total nitrogen (%)	0.05

T_8 100 kg N/ha as ammonium nitrate, with 10 kg $ZnSO_4$/ha.

Experiment consisting of eight (8) treatments was laid out in a completely randomized design. Crop was irrigated with distilled water, throughout the growth-period, and was harvested at maturity. Oven dry weight of grain and straw was recorded. Grain and straw samples were analyzed for N by Kjeldahl method (Bhargra and Raghupathi., 1993) and Zn by atomic absorption spectrophotometer. The data for paddy and straw-yield and their chemical composition was analyzed statistically and LSD was used for mean separation (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Paddy and Straw-Yield

Different nitrogen sources, used alongwith zinc, significantly increased paddy and straw-yield of rice (Table 2). Ammonium sulfate used as N source was better than rest of the sources. Paddy and straw-yield obtained in different nitrogen-sources, used without zinc, was minimum and statistically similar with each other. Rice gave significantly higher yield as 25% in grain and 14 % in straw with ammonium sulfate - zinc, and 28% in grain and 13 % in straw with urea-Zn, as against 19 and 9% in grain and straw, respectively, with calcium ammonium nitrate-Zn and only 12 and 9% with ammonium nitrate-Zn, over their respective control. Some earlier studies have also shown that Zn used alongwith nitrogen (Singh *et al*., 1995; Tahir and Kausar, 1994; Singh and Singh, 1981) increased crop-yields. On the contrary, though application of Zn alongwith N to rice stimulated plant growth, but it decreased grain weight and paddy yield due to Cu deficiency at later stages (Alam *et. al*., 1997). Ammonium sulfate, used with and without Zn, was superior to all other sources. Probably more reduction of soil pH in ammonium sulfate increased the Zn-availability and its useful effect on rice-growth and yield. These results are also in agreement with those of Shinde and Patil (1980) and Amer *et al*. (1980).

A significant improvement in paddy : straw ratio was observed by application of Zn (Table 2). Probably increased grain-weight and percentage of filled grain per panicle were due to Zn application (Tahir and Kausar, 1994). Grain to straw ratio in T4 (ammonium sulfate + Zn) was significantly higher than T6 (CAN+Zn) and T8 (ammonium nitrate + Zn). The higher paddy to straw ratio in ammonium sulfate-Zn was possibly due to availability of more Zn and more number of filled grains under reduced pH (Tahir *et. al*., 1992). The differences in grain to straw ratio among all nitrogen sources without zinc were non-significant. Perhaps deficiency of Zn produced small-sized grains and low percentage of filled grain per panicle. Similar results were reported by Singh *et al*. (1995).

Nitrogen Concentration and Uptake

Application of zinc alongwith nitrogen enhanced nitrogen concentration, both in grain and straw (Table 3). Nitrogen concentration was significantly higher in

Table – 2: Effect of nitrogen sources and zinc on paddy, straw yield and paddy: straw ratio in rice

Treatment	Paddy yield	Straw yield	Paddy : Straw ratio
	----------(g/pot)----------		
T1	36.1d	47.4e	0.72b
T2	46.1b	53.3b	0.87a
T3	39.9c	51.2bc	0.76b
T4	49.9a	58.4a	0.91a
T5	34.5d	45.8e	0.75b
T6	41.0c	49.7cd	0.76b
T7	33.5d	45.5e	0.68b
T8	39.8c	49.6cd	0.74b

Means sharing the same letter (s) are statistically non-significant at < 0.05 probability.

Table – 3: Effect of nitrogen sources and zinc on N concentration and uptake by rice

Treatment	N concentration		N-uptake	
	Grain	Straw	Grain	Straw
	----------(%)----------		----------(g/pot)----------	
T1	1.09a-c	0.56bc	0.39c-e	0.27d
T2	1.15ab	0.60b	0.53b	0.31b
T3	1.10a-c	0.55bc	0.44c	0.29c
T4	1.19a	0.70a	0.60a	0.40a
T5	0.99c	0.48c	0.34de	0.23f
T6	1.02bc	0.51c	0.42c	0.25f
T7	0.98c	0.49c	0.33e	0.23f
T8	1.03bc	0.53bc	0.40cd	0.26e
SE.	0.046	0.026	0.02	0.015

Table – 4: Effect of nitrogen sources and zinc on Zn concentration and uptake by rice

Treatment	Zn concentration		Zn-uptake (g/pot)
	Grain	Straw	
	----------(mg/kg)----------		
T1	12.0c	16.0c	1.19f
T2	20.0ab	24.6ab	2.23b
T3	14.3bc	16.3c	1.41d
T4	22.0a	26.6a	2.60a
T5	11.2c	15.0c	1.07g
T6	15.3a-c	21.6b	1.70c
T7	11.6c	16.3c	1.29e
T8	16.6a-c	22.0b	1.66c
SE.	2.267	1.167	0.096

T4 than T6 (CAN + Zn) and T8 (ammonium nitrate + Zn), but values were at par with T2 in grains. In rice straw, only T4 gave significantly higher N concentration. Treatment T2 (urea + Zn), T6 (CAN + Zn) and T8 (AN + Zn) were statistically non-significant in difference with respect to N values. The treatments where no Zn was applied, nitrogen concentration decreased both in grain and straw. The results are in agreement with the observations of Singh *et. al*., (1995). Dev and Shukla (1982) stated that ammonium sulfate is the better source, with respect to improvement of nitrogen content in rice. Nitrogen uptake, both in paddy and straw, was significantly affected by zinc and nitrogen application (Table 3) . Maximum increase in N uptake was found in T4 (ammonium sulfate + Zn) followed by T2 (Urea + Zn) which, in turn, was statistically different from T6 (CAN + Zn) and T8 (AN + Zn). Fertilization of N and Zn together had synergistic effect on uptake of each other (Chaudhry *et. al*., 1977). In the absence of Zn, plant growth was stunted and nitrogen uptake was relatively smaller.

Nitrogen uptake in grain for T3 (ammonium sulfate) was statistically similar to T1 (urea), but was significantly higher than T5 (CAN) and T7 (AN). Nitrogen uptake in rice-straw was significantly higher in T3 (ammonium sulfate) than T1 (urea), T5 (CAN) and T7 (AN). With application of Zn, higher N uptake in rice is quite evident from the data. Similarly, nitrogen uptake in rice for ammonium sulfate was better than other N sources. Singh *et al*. (1995) and Tahir and Kausar (1994) also recorded higher N uptake in rice where it was applied with Zn, rather than applying nitrogen alone. Urea, ammonium nitrate and calcium ammonium nitrate used were at par with each other. They did not affect N concentration and uptake in rice-grain significantly.

Zinc Concentration and Uptake

Concentration of Zn, both in grain and straw, as well as total uptake increased significantly by application of Zn alongwith different nitrogen sources (Table 4). Concentration and total uptake of Zn was found maximum in T4 (ammonium sulfate + Zn), followed by T2 (Urea + Zn) and T8 (ammonium nitrate +Zn). Having more acidifying effect on soil than other N sources, ammonium sulfate increased growth and availability of Zn in rice. Chaudhry *et. al*. (1977) also reported similar increase in Zn content of rice plants. In case of urea, uptake and translocation of Zn was depressed due to interference by HCO_3 ions in plants. In another study, urea applied with Zn to rice has shown good effect on yield and Zn content in rice (Singh and Singh, 1981). In the treatments where Zn was not applied, Zn concentration and uptake in rice was low. Stunted rice growth in the absence of Zn, perhaps depressed Zn uptake in plants (Tahir and Kausar, 1994). There was non-significant difference among N-sources used. The treatment T3 (ammonium sulfate) was better than T1 (urea) and T7 (ammonium nitrate). Acidic nature of ammonium sulfate probably improved the Zn uptake. The results are in good agreement with those reported by Singh and Singh (1995).

CONCLUSION

Application of N along with Zn increased paddy yield and paddy-to-straw ratio significantly. Among the different N sources used, ammonium sulfate enhanced paddy yield more than other sources. Use of N alone was not so helpful in improving growth and paddy yield. Application of N along with Zn had synergistic effect on N and Zn uptake in rice.

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EFFECT OF DICYANDIAMIDE (DCD) AND PYRETHRUM FLOWER-WASTE ON GROWTH AND MENTHOL-CONTENTS OF *MENTHA ARVENSIS L.*

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ABSTRACT

Pyrethrum (Chrysanthemum cinerariefolium) flowers have been observed to have insecticidal properties and could be used as indigenous nitrification inhibitors for increasing N-use efficiency and growth. A field experiment was conducted at National Agricultural Research Centre, Islamabad, during 1998 and 1999, to evaluate the relative performance of pyrethrum flower-waste and Dicyandiamide (DCD) as nitrification inhibitors, applied with prilled urea (PU) to Japanese mint (Mentha arvensis L.) The results revealed that application of the nitrification inhibitors with prilled urea significantly increased the growth and menthol contents of the crop, compared to that of prilled urea alone. Addition of DCD and pyrethrum flower-waste gave 30% and 23% more herb-yield than prilled urea alone, the corresponding increase in oil-contents being 27% and 22%, respectively. Application of nitrogen at 200 kg ha^{-1} in dicayndiamide or pyrethrum flower waste-treated soil enhanced the growth and menthol contents of crop significantly more than that for 300 kg N ha^{-1} with prilled urea. Both the materials improved the N use-efficiency one and half times, compared to that with PU at 100 kg N ha^{-1}. The results indicate that pyrethrum flower-dust can be effectively used as a potential nitrification inhibitor.

INTRODUCTION

Japanese mint is an important essential-oil-bearing crop, cultivated for menthol, used in cosmetic and pharmaceutical industry. It is generally planted in January-February in the plains of Punjab, Pakistan. *Mentha arvensis* is a herbaceous plant, usually grown in loamy to clayey loam soil. On the average, it requires 120 kg ha^{-1} N for optimum growth. Frequent irrigations are generally given during the entire growth-period of this crop, till the monsoon comes.

A loss of N due to NO_3 leaching is a serious problem in the medium-textured soils of Punjab. This loss is considered to be greater during the rainy season. This results in a very poor N-use efficiency.

Commercial nitrification-inhibitors are recommended for application with ammonium and ammonium-producing fertilizers, to retard the formation of nitrate by nitrifying bacteria and thus reduce the loss by leaching and denitrification. Many plant-products and by-products have also been reported to have nitrification-inhibitory properties and have successfully been used to retard nitrification in soil (Sivapalan & Fernando, 1985., Prakasha and Puttana, 1994., Sharma and Prasad, 1996).

Pyrethrum flowers are grown for their insecticidal and ornamental properties. Preliminary investigations have indicated that pyrethrum also has unique nitrification inhibitory properties (Ram *et al.*., 1993). The aim of the present work was to evaluate the relative performance of pyrethrum flower-waste and DCD as inhibitors for reducing N losses and increasing growth and menthol-contents of mint.

MATERIALS AND METHODS

A field experiment was conducted for two years, during 1998 & 1999, at NARC, Islamabad, Pakistan. The soil of the experimental plot was loam in texture and had pH 7.8, EC 0.25dSm^{-1}, available N 0.04%, available K 0.76 mg kg^{-1}, and P 4.5 mg kg^{-1}.

The treatments consisted of three combinations of nitrogen and nitrification inhibitors, viz prilled urea + no inhibitor, urea + dicyandiamide (DCD) and urea + pyrethrum flower waste, with three levels of nitrogen (100, 200 and 300 kg ha^{-1}) and one control. The statistical design was a randomized block-design with three replications.

Suckers of Japanese mint were transplanted end-to-end in the last week of January in 5 cm deep furrows, 40 cm apart and covered with 5 cm soil. Nitrogen was applied in two equal splits i.e., at planting and after first harvest. Dicyandiamide was applied at planting time @ 15 ppm on soil-basis, considering the plough-depth having a bulk density of 1.47 g cm^{-3}. This was thoroughly mixed with the soil. Pyrethrum flower-waste, a by-product of medicinal plant (100 ppm on

soil basis) was also applied at planting-time and thoroughly mixed with the soil. The crop, both in the control and N plus inhibitor-treated plots, received a uniform application of 60 kg ha^{-1} each of P and K at the time of planting, as single super-phosphate and muriate of potash, respectively. Two harvests of the herb, 15 days after planting (DAP) and 75 days after first harvest, were taken during 1998. However, in 1999, only first harvest, 115 days after planting, was taken because a second harvest from the regenerated crop was not possible due to heavy rains.

Soil samples were collected at 0-15 cm and 15-25 cm depth, randomly, from five sites in each plot at 30 days after planting, 60 days after planting and after first harvest, and analysed for ammoniacal and nitrate form of N, by the procedures described by Jackson (1967) and Black *et al.* (1965). Mineral N is presented in kg ha^{-1}, taking bulk density of the soil 1.47 g cm^{-3} and soil depth 15 cm; 1 hectare soils weighs 2.205 x 10^6 kg. The soil pH, EC, mineral N and soil-texture was determined by the method described by Winkleman *et al*. (1990). Values for tissue P and K were obtained by atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Growth and Menthol Contents

Dicyandiamide (DCD) and pyrethrum flower-waste significantly increased the growth and menthol contents in Japanese mint, over prilled urea (Table 1). The increase in growth was in the order of 37 and 27 % by DCD and pyrethrum, respectively, over prilled urea (PU) in 1998. The corresponding increase in 1999 was 23 and 18 %, respectively. On application of 300 kg ha^{-1} N, the maximum growth observed was 17 t ha^{-1}, compared to 4.1 t ha^{-1} of control (Table 1). It might be due to high utilization of N by the crop, as a result of retardation-loss of fertilizer N by the nitrification inhibitors. The usage of DCD as a potential inhibitor has been reported by several workers in upland condition. (Sharma and Prasad, 1996; Arshad *et al.,* 1999). Pyrethrum flower-waste application significantly improved the growth, compared to the prilled urea, although rate of increase was low compared to DCD. Pyrethrum flower-waste is thought to have some nitrification inhibitory properties (Ram *et al.*, 1993), as in several naturally occuring plant-materials (Sahrawat, 1982; Sharma and Prasad, 1996). The inhibitory properties of pyrethrum flower-waste may be attributed to the residual quantity of pyrethrin, which is known to be a domestic insecticide. The same insecticidal properties have played a vital role in limiting the process of nitrification.

Dicyandiamide and pyrethrum flower-waste increased the menthol contents over prilled urea by 23% and 20% in 1998 and 31% and 21% in 1999. Both growth and menthol-contents increased with increasing rate of nitrogen application. Substantial increases in herb and essential-oil yield of Japanese mint, due to high levels of N, have been reported by Sharma and Singh (1980) and Ram *et al.* (1989).

Interaction effects, amongst nitrification-inhibitors and N-rates, showed that growth and menthol-contents were significantly increased at 200 kg N ha^{-1} applied with DCD or pyrethrum flower-waste, compared to 100 kg N ha^{-1} urea applied alone or with DCD or pyrethrum waste and 200 and 300 kg N ha^{-1} applied as PU alone, during both the years (Table1). Obviously, application of N at 200 kg ha^{-1} with DCD or pyrethrum flower-waste economized 100 kg N ha^{-1}. Higher growth and menthol-contents with inhibitor may be due to inhibition of nitrification-process in soil, resulting in reduced nitrogen-losses through different mechanisms.

Mineral nitrogen status of soil

The data on status of NH_4–N and NO_3–N, estimated at 30 and 60 days after planting (DAP), and at first harvest (115 DAP), reveal that NO_3–N was the lowest in DCD-treated plot, followed by that in pyrethrum-treated plots (Table 2 and 3). This indicates retardation of nitrate formation by both the nitrification inhibitors. Many studies have shown that nitrification inhibitors can be used to enhance NH_4–N, supply, particularly when reduced nitrate-movement to groundwater is increasing the proportion of N supplied to the crop as NH_4–N (Ball-Coelho, 1999). In 1999, however, the nitrate content, which was lower in DCD treated soil than in the pyrethrum treated soil in the early stages, was found at par during the later stages (60 DAP and first harvest). Our results are in agreement with those of Puttana *et al*. (1999), which indicated that concentrations of the inhibitors in soil delayed the nitrification up to 60 days. Another reason behind that is reduced N-leaching, because restricted post-

Table – 1: Growth and Menthol Contents of Japanese mint, as affected by different nitrification inhibitors and nitrogen level

N-rate (kg ha-1)	Growth (t ha^{-1})				Menthol Content (kg ha^{-1})			
	PU*	DCD	PF	Mean	PU	DCD	PF	Mean
1998								
100	8.6	10.2	9.9	9.6	59	68	70	66
200	10.5	14.9	13.9	13.1	80	101	96	92
300	11.8	17.0	15.5	14.8	91	111	105	102
Mean	10.3	14.0	13.1		76	93	90	
Control				4.1				25
C.D. 5% control vs N-rates				1.2				9
C.D. 5% for inhibitors				0.8				6
C.D. 5% for N-rates				0.8				6
C.D. 5% for N-rates x Inhibitors				1.4				11
1999								
100	11.9	14.5	14.0	13.5	96	126	114	112
200	13.2	15.8	15.3	14.7	110	138	128	125
300	13.3	16.7	16.2	15.4	110	149	143	134
Mean	12.8	15.7	15.2		105	138	128	
Control				3.8				33
C.D. 5% control vs N-rates				1.0				9
C.D. 5% for inhibitors				0.7				6
C.D. 5% for N-rates				0.7				6
C.D. 5% for N-rates x inhibitors				1.2				11

*Prilled urea, DCD – Dicyandiamide, PF – Pyrethrum Flower waste

Table – 2: Nitrogen forms in soil (kg ha $^{-1}$)

Treatment	1998				After first harvest	
	30 DAP*		60 DAP		115 DAP	
	NH^4	NO^3	NH^4	NO^3	NH^4	NO_3
Nitrification inhibitors						
Prilled urea	99	95	56	37	33	32
Dicyandiamide	101	75	47	30	26	25
Pyrethrum flower dust	96	86	55	35	30	28
C.D. 5%	3.92	4.12	3.45	2.63	1062	1.64
Nitrogen Levels (kg ha^{-1})						
100	85	78	45	30	28	24
200	89	84	52	33	30	28
300	98	94	60	39	32	32
C.D. 5%	3.88	4.1	3.40	2.65	1.65	1.60
Control	88	48	23	22	23	18
C.D. %5 control vs N-levels	5.44	5.68	4.70	3.65	2.45	2.40

*DAP – Days After Planting

Table – 3: Nitrogen forms in soil (kg ha^{-1})

Treatment	1999				After first harvest	
	30 DAP*		60 DAP		115 DAP	
	NH^4	NO^3	NH^4	NO^3	NH^4	NO_3
Nitrification inhibitors						
Prilled urea	148	123	103	67	96	56
Dicyandiamide	127	92	92	53	90	46
Pyrethrum flower dust	135	101	97	55	95	48
C.D. 5%	11	3.85	4.25	3.45	4.45	2.45
Nitrogen Levels (kg ha^{-1})						
100	125	96	91	51	87	43
200	129	105	95	57	91	49
300	156	115	106	66	103	58
C.D. 5%	11.1	3.85	4.22	3.45	4.46	2.44
Control	94	71	70	51	38	26
C.D. %5 control vs N-levels	16	5	6.00	4.85	6.28	3.45

*DAP Days after planting

harvest leaching of N has been reported when DCD was applied as nitrification inhibitor (Chen *et al*., 1998). Not only this, but reduction in N_2O emission from soil-plant system is another effect of these inhibitors. (Chen *et al*., 1998). These inhibitory properties of pyrethrum flower-waste appear to have started later, compared to DCD. In general, the NH_4–N content was the lowest in the DCD treated soil, followed by the pyrethrum-treated soil and the highest with prilled urea. Lower NH_4 in the soil treated with inhibitors is unusual, but could be due to greater plant-growth and enhanced uptake of NH_4–N. The NH_4–N inhibition with DCD and pyrethrum seems to be the result of chemical properties possessed by the inhibitory compounds of both. On the other hand, urea has two amino groups in its molecular structure that, during NH_4–N inhibition, antagonize the chemical-configuration, thus curtailing the inhibition process.

CONCLUSION

The above results demonstrate an interrelation between N-rates and nitrification inhibitors on increasing N-use efficiency, with respect to yield of Japanese mint. There was a significant interaction between N-rates and inhibitors. Nitrogen applied at 200 kg N ha^{-1}, with inhibitors, showed a significant increase in growth and menthol-contents over the 200 and 300 kg N ha^{-1} applied as prilled urea (no inhibitor). Herb-yield significantly increased with an increase in the level of N up to 300 kg in DCD-treated plots. But the increase was restricted up to 200 kg N ha^{-1} with PU and pyrethrum. Mean of two years' data indicated an increase of 34% and 26% in herb-yield over prilled urea at 300 kg N ha^{-1} with DCD and pyrethrum, respectively. The corresponding increases in menthol-contents were 29% and 23%, respectively.

Our study shows that the use of nitrification-inhibitors is favourable for high-N demanding crops, particularly for those crops that are grown in N deficient, poorly structured and leaching-prone soils. The results reveal that pyrethrum flower-waste can be effectively used as a potential nitrification-inhibitor, although it is not as efficient as DCD.

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EFFECT OF NITRIFICATION INHIBITORS ON NITROGEN-FIXING BACTERIA

*Muhammad Arshad**

ABSTRACT

The nitrification inhibitor dicyandiamide (DCD) did not inhibit the growth and respiration of N-fixing bacteria (Rhizobium leguminosarum Azotobacter chroococcum) in cell-suspensions with concentrations of 400 m gm^{-1} DCD. Growth of Rhizobium legumiinosarum was inhibited by 17% with 100 m gm^{-1} nitrapyrin (N serve), but respiration was not affected. [Growth of Azotobacter chroococcum was inhibited by 10 m gm^{-1} (10%) and 100 m gm^{-1} nitrapyrin (50%), in the latter case, respiration was also impaired (36%); thiourea only caused a minor growth-inhibition of Azotobacter chroococcum with 100 m gm^{-1} (8%) and had no effect on Rhizobium leguminosarum.

INTRODUCTION

One of the most important requirements for nitrification-inhibitors is specificity for bacteria of the species *Nitrosomonas europaea,* which perform the first step of nitrification. Impact on other soil-bacteria should be negligible or as low as possible. Symbiotic and non-symbiotic N-fixing bacteria of the genus Rhizobium and Azotobacter should especially not be impaired in their activity. The strong inhibiting effect of nitrification-inhibitors on N-fixing bacteria had been reported by different researchers: Hughes and Welch, 1970, Vannelli and Hooper 1993, and Bedard and Knowles 1997.

The objective of this study was to determine the effect of the nitrification-inhibitors, Dicyandiamide (DCD), N serve (NS) and Thiourea (TU), on growth and respiration of Rhizobium and Azotobacter.

Materials and Methods

The two strains, *Rhizobium leguminosarum* and *Azotobacter chroococcum,* were cultivated in the following nutrient solution:

D (-) Mannite	10.0 g
K_2HPO_4	0.5 g
$MgSO_4 + 7H_2$	0.2 g
NaCl	0.1 g
Yeast extract	1.5 g

pH 7.2 (adjusted after autoclaving).

The stock cultures grew on solid nutrient media. Petri dishes were prepared from the above nutrient-solution, after addition of 1.5 % agar, and inoculated by means of a loop.

Both microorganisms were cultivated in the above-mentioned nutrient solution. At first, inoculated medium was incubated at 25 ^{0}C on a rotary shaker; this preliminary culture was used as an inocolum after optical density was adjusted to 1.2 (578 nm). Five replicates of each treatment were started with 10ml nutrient solution plus respective amounts of inhibitors in flasks. The flasks were inoculated with 0.1 ml of the preliminary culture and shaken in the warm water-bath at 25 ^{0}C. After 20 h, the turbidity of the nutrient solution was measured, using a spectrometer (578nm).

Bacteria were pre-cultivated for 20h, then centrifuged (3500 rpm) and washed twice with 0.1 M phosphate buffer (pH 7.2). From this suspension, 1.5ml were pipetted together with 0.5 ml glucose (1 %) into the main part of warburg flasks. The center-well contained 0.2 ml KOH (5%). The nitrification inhibitors were pipetted into the side-arm and added after a preliminary run of 30 minutes. All measurements were done in 6 replicates at 28 ^{0}C.

RESULTS

1. Growth and respiration of Rhizobium

Among the tested inhibitors, only N-serve at the higher concentration of 100 m gm^{-1} affected growth of Rhizobium with significant depression of 17% (Figure-1). Respiration was not impaired in any case. The respiration rates of inhibitor-treatments and untreated controls were almost identical (Table-1). The untreated bacteria consumed 215

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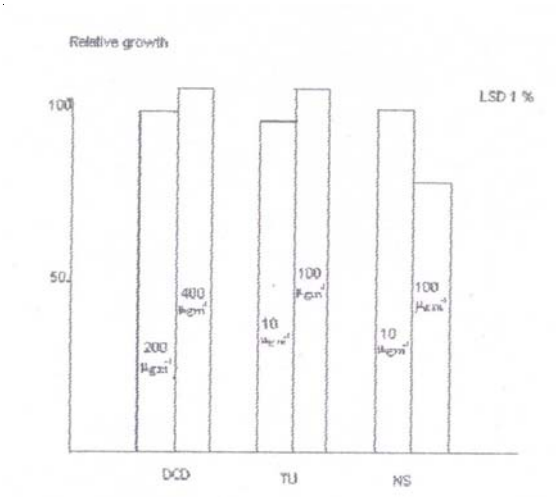

Figure - 1: Effects of inhibitors on relative growth of Rhizobium leguminosarum (control=100) (DCD=dicyandiamide, TU=thiourea, NS=nitrapyrin)

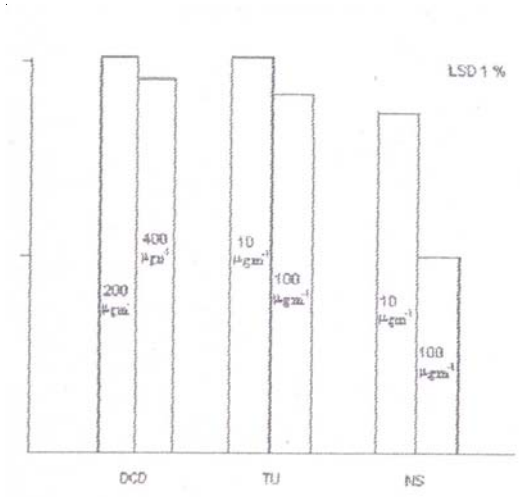

Figure - 2: Effects of inhibitors on relative growth of Azotobacter chroococcum (control=100) (DCD=dicyandiamide, TU=thiourea, NS=nitrapyrin)

ml oxygen during the experiment. All the 3 inhibitors led to a slightly increased respiration which, however, was never significant.

2. Growth and respiration of Azotobacter.

As compared to Rhizobia, the growth of asymbiotic Azotobacter bacteria was more sensitive to nitrification inhibitors (Figure-2). While 200 m gm^{-1} DCD, 400 m gm^{-1} DCD and 100 m gm^{-1} Tu did not affect the growth, the other treatments resulted in significant depressions of growth by 8% (100 m gm^{-1} TU). 10% (10 m gm^{-1} NS) and 50% (100 m gm^{-1} NS). Respiration was not affected to the same extent (Table-1). Dicyandiamide and thiourea did not reduce respiration, as compared to control. With 10 m gm^{-1} N-serve, however, total oxygen consumption over a 2h period was lowered by 36%, which was due to stagnating respiration at the beginning of the experiment. After half an hour, respiration increased similar to other treatments.

DISCUSSION

In this study, respiration was selected as the most sensitive parameter to be measured, because N-fixing bacteria have a very intensive respiration due to their high energy-demand to reduce N_2. Therefore, a depression in respiration-rate by a nitrification inhibitor would be expected to result in reduced N_2 fixation. The results of this study revealed their DCD is non-toxic to two important N_2 fixing bacterial genera, even at very high concentrations (400 m gm^{-1}). However, it delayed the bacterial oxidation of ammonium ions by depressing the activities of *Nitrosomonas* in the soil for a certain period of time. Thus, there is a need for further studies to be carried out on the manipulation of DCD doses to study the critical relationship of *R. leguminosarum* with host-plant included in the study. Stichlmair (1984) demonstrated that C-heterotrophic soil microoganisms (eg Arthrobacter sp., Bacillus sp.) and important soil-enzymes are also not affected by 400 m gm^{-1} DCD. In long-term field trials (53 years) with calcium cyanamide (containing 10% DCD), only positive effects on soil biological activities were observed by Bosch and Amberger (1983).

Thiourea surprisingly did not have a toxic effect on N-fixing bacteria in pure culture, even though it had been classified earlier as highly toxic for soil microorganisms by Frederick *et al* (1957) and Zacherd and Amberger (1990). N-serve, while having only a small effect on Rhizobium, strongly affected the non-symbiotic Azotobacter bacteria. The results are similar to Chamber *et al.* (1980), in which N-serve was defined as toxic for N-fixing bacteria and mycorrhizae. N-serve thus does not fulfill the ecological requirement of specifically inhibiting only on Nitrosomonas sp. Prevalence of nitrification inhibitor shows its control

Table – 1: Oxygen consumption of Rhizobium and Azotobacter within 2 hours

Treatment* *Chroococcum* %	*Rhizobium* $\mu 10_2$	*leguminosarum* %	*Azotobacter* μlCo_2
Control 100	215	100	177
400 μ gm^{-1} DCD 95	217	101	169
100 μ gm^{-1} Tu 96	230	107	170
100 μ gm^{-1} Ns 64	222	103	114
L.S.D. 1%	18		15

* DCD - Dicyandiamide
Tu-Thiourea; Ns-Nitrapyrin (N-Serve)

on nitrogen-fixing bacteria in the soil, which transfer ammonia into nitrite and then these nitrities into nitrates.

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SEED-BORNE PATHOGENS ASSOCIATED WITH CERTIFIED SEED LOTS OF WHEAT IN PAKISTAN

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ABSTRACT

Ten seed-borne pathogens were detected from 335 wheat seed samples that were collected from twelve major wheat-growing areas in Pakistan during 1997-98,1998-99 and 1999-2000. Fusarium spp were the major pathogen, with infection ranging from 0.5 to 34.0 per cent. Bipolaris sorokiniana was the second major pathogen, with infection ranging from 0.50 – 28.0 per cent. Acremonium spp. was isolated from Peshawar and D.I.Khan, while Microdochium nivalis was isolated only from D.I.Khan. Bipolaris tetramera, Curvularia lunata, Phoma spp.. and Stemphylium spp. were detected, with infection less than 2 per cent.

Variation in number of pathogens and their incidence was found from year to year. High incidence of pathogens suggests that wheat seed should be tested for their health status, regularly and infected seed-lots should be treated with seed-dressing fungicides before sowing. Alternaria tenuis, Aspergillus spp., Bipolaris hawiiensis, Cladosporium spp., Epicocum spp., Penicillium spp., and Rhizopus spp. were also identified, but were not counted.

Key words. Seed-borne pathogens , wheat seed lots , Pakistan

INTRODUCTION

The major diseases of wheat in Pakistan are rusts, loose smut, bunts, septoria leaf spot, foot rot, root rot, black point complex and ear cockle (Kausar, 1955). Spot blotch caused by *Bipolaris sorokiniana* is the most severe disease of warmer areas. Yield-loss from 40% to 85% had been reported in Philippines and Zambia, respectively.(Lapis, 1985 and Raemaekers, 1988) Pink snow mold, caused by *Microdochium nivale,* has also caused substantial yield-loss (Mathur & Cunfer, 1993). In Pakistan, losses due to different wheat-diseases are also considered high. In view of this scenario, 335 seed samples of wheat were collected from fields that were inspected and certified by the Federal Seed Certification and Registration Department for seed-production and were tested for their health-status using ISTA techniques. Data about the incidence and association of pathogens with wheat seed may be very useful to the breeders and seed technologists, at national and international level, for planning better strategies on disease-management in wheat crop.

MATERIALS & METHODS

A total of 335 wheat-seed samples were collected from different agro-ecological regions, as described in Agro-ecological regions of Pakistan (Anonymous, 1980) according to ISTA rules(1985), during 1997-98, 1998-99 and 1999-2000. The seeds were tested by the standard blotter-paper method (Neergard, 1979). Three blotter papers, well moistened in sterilized water, were placed in each Petri dish .Four hundred seeds were placed in such a manner that each Petri dish may contain 25 seeds. Seeds were incubated at 20°C±2°C for 7 days and on 8th day, seeds in Petri dishes were examined under stereo-microscope and, wherever identification was difficult, slides were prepared and examined under binocular electric microscope on the basis of spore shape, size, its attachment with fruiting body directly from seed. (Chidambaram et al, 1973, Nath et al, 1970, and Barnette, 1960). Detail and percentage infection of the pathogens is given in Table-1.

RESULTS AND DISCUSSION

Ten important seed-borne pathogens were identified from the infected seed-samples out of 335 tested during this study (table-1). The most commonly occurring pathogens were *Fusarium spp. (Fusarium moniliforme, F.oxysporum, F. semitectum and F. solani). F. moniliforme,* with infection of 34.00 and 19.50 per cent, was found in samples collected from Khanewal and D. I. Khan and, similarly, *F. semitectum* was found as 11.00 and 10.50 per-cent in seed samples from Khanewal and Sakrand, during 1997-98 and 1998-99, respectively. Seeds infected with high percentage of *Fusarium spp*. may fail to germinate or may give rise to blighted seedlings, especially if infected seeds are planted in warm dry soil (Mathur and Cunfer 1993*).Fusarium spp.,* primarily soil-borne pathogen to many crops (Trenholm et al, 1981), are

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Table - 1: Wheat seed samples tested for fungal pathogens, during 1997-98 to 1999-2000

1997-98			1998-99			1999-2000		
No. of sample tested	Locality and Pathogen	Infection %age range	No. of samples tested	Locality & Pathogen	Infection %age range	No. of samples tested	Locality & Pathogen	Infection %age range
1	***2***	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	***Islamabad***		4			9		
	Bipolaris sorokiniana						B.s	0.00- 0.50
	Bipolaris tetramera						B.t	0.00- 0.50
	Fusarium moniliforme	0.00-7.50		F.m	0.50-5.50		F.m	0.50- 2.00
	Fusarium semitectum	0.50-1.50		F.s	0.50-1.50		F.s	0.00- 0.50
	Phoma spp.			Ph. spp.	0.00-1.50			
12	***Lahore***		4			12		
	Bipolaris sorokiniana	0.50-6.50		B.s	0.50- 9.50		B.s	0.00- 0.50
	Curvularia lunata			C.l	0.50-1.50			
	Fusarium moniliforme	0.50-2.00					F.m	0.50- 1.00
	Fusarium semitectum	0.00-0.50		F.s	1.00-2.50		F.s	0.00- 0.50
	Stemphelium spp.			St. spp.	0.50- 1.50			
11	***Sahiwal***		5			18		
	Bipolaris sorokiniana	0.00-0.50		B.s	0.00- 1.00		B.s	0.50- 2.00
	Fusarium moniliforme						F.m	0.50- 2.00
	Fusarium semitectum	0.00-1.00		F.s	0.00- 1.00		F.s	0.00- 0.50
	Phoma spp.						P.spp	0.05- 1.00
	R. Y. Khan		10			19		
	Bipolaris sorokiniana			B.s	1.00- 3.50		B.s	0.50- 2.00
	Fusarium moniliforme						F.m	0.50- 2.50
	Fusarium semitectum						F.s	0.50- 2.50
	Phoma spp.						P.spp.	0.00- 0.50
	Khanewal		52			10		
	Bipolaris sorokiniana			B.s	3.00- 28.00		B.s	0.00- 0.50
	Fusarium moniliforme			F.m	0.50-34.00		F.m	0.50- 2.50
	Fusarium semitectum			F.s	0.50-11.00			
	Fusarium solani				0.00-0.50			
	Phoma spp				0.00-1.50			
	Multan		(-)			23		
	Bipolaris sorokiniana						B.s	0.50- 4.00
	Bipolaris tetramera						B.t	0.50- 1.00
	Fusarium moniliforme						F.m	0.00- 0.50
	Phoma spp.						P.spp	0.50- 1.00
12	***Peshawer***		4			39		
	Bipolaris sorokiniana	0.50-14.50		B.s	2.00- 3.00		B.s	0.50- 4.00
	Curvularia lunata.	0.50-7.50						
	Fusarium moniliforme			F.m	0.00- 1.00		F.m	0.50- 8.00
	Fusarium semitectum	0.00-2.50		F.s	0.50- 2.00		F.s	0.50- 5.50
	Phoma spp			P. spp.	0.00- 0.50			

Continued...

Continued…

	Acremonium spp.			Ac. sp.	0.00- 0.50			
12	***D.I. Khan***		10			10		
	Acremonium spp.	0.00-0.50						
	Bipolaris sorokiniana	0.50-12.0		B.s	1.00-2.50			
	Bipolaris tetramira	1.00-1.50						
	Cuvularia lunata.			C.l.	0.5 -1.50			
1	***2***	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Fusarium moniliforme	0.00-19.50		F.m	0.00- 0.50		F.m	0.50- 2.50
	Fusarium semitectum	0.50-4.00		F.s	0.50-1.50		F.s	5.00- 3.50
	Microdochium nivalis	0.00- 0.50						
	Phoma spp.	0.00- 0.50		P. spp.	0.00- 0.50		P.spp.	0.00- 1.00
3	***Quetta***		2			2		
	Bipolaris sorokiniana			B.s	0.50- 1.50		B.s	0.50- 1.50
	Bipolaris tetramera						B.t	0.00- 0.50
	Curvularia lunata.			C.l.	0.00-1.00			
	Fusarium moniliforme	1.50- 6.50					F.m	0.50- 1.00
	Fusarium semitectum	0.00- 1.00					F.s	0.00- 0.50
	Stemphylium spp.			St.spp.	0.00- 1.00			
11	***Hyderabad***		14			9		
	Bipolaris sorokiniana	0.50- 1.50		B.s	0.50- 1.00		B.s	0.50- 2.00
	Bipolaris tetramera	0.50 -1.00						
	Curvularia lunata.			C.l.	0.50- 1.00			
	Fusarium moniliforme	1.00- 8.00					F.m	1.00- 2.50
	Fusarium semitectum	0.50- 2.00					F.s	0.00- 1.00
	Phoma spp.	0.50- 1.00						
	Stemphylium spp.			St. spp.	0.00-1.50			
3	***Sakrand***		8			(-)		
	Bipolaris sorokiniana	0.50- 1.50		B.s	0.50- 4.00			
	Curvularia lunata.			C.L.	0.50-1.50			
	Fusarium moniliforme	2.50-10.50						
	Fusarium semitectum	0.50- 3.00						
	Stemphylium spp.				0.00-1.50			
4	***Sukkur***		(-)			(-)		
	Bipolaris sorokiniana	0.50- 5.50						
	Fusarium moniliforme	1.50- 2.50						
	Fusarium semitectum	1.50-10.50						
	Fusarium solani	0.00-1.50						

(-) Seed samples were not available.

known to produce mycotoxin viz. *Zeralenone, moniliformine* and fusaric acid (Diener et al, 1981).

The second most commonly occurring pathogen was *Bipolaris sorokiniana* (sacc.) shoem., identified from all localities except Islamabad, during 1998-99, and from D.I.Khan during 1999-2000. Its highest infection was found up to 28.00 per cent from Khanewal area, during 1998-99, but minimum infection level of 0.50% was found in seed samples from Sahiwal, during 1997-98, and from Islamabad, Khanewal and Lahore during 1999-2000. Bhutta and Hussain (1999) have also reported 0.5 to 11% infection of *B. sorokiniana* in samples collected all over Pakistan .This pathogen can adversely affect germination and sometime kills the seedlings (Mathur & Cunfer, 1993)Yield losses caused by this fungus are not known yet in Pakistan.

Acremonium spp. was identified from Peshawar and D.I.Khan seed samples, while *Microdocium nivalis* (Fr.) Samuels & I.C. Hallet was found only from D.I.Khan. *Phoma spp*. was identified from samples of central and southern Punjab, Sindh and southern part of NWFP provinces. Other pathogens, such as *Bipolaris tetramera* (Mckinney) shoem, *Curvularia lunata* (wakker) Boedijn and *Stemphylium spp*. were also detected from some localities, with infection percentage range from 0.5 to 2.0. In previous studies, it was reported that seed-borne pathogens showed decreasing trend in southern part of the country (Khan and Bhutta, 1994), but in this study, increasing trend was observed. It may be due to the fact that movement of untreated seed from one part of the country to other part of the country has been very often by the private sector.

Keeping in view the distribution and incidence of fungal seed-borne pathogens, wheat seed lots should be regularly monitored for their health-status using seed-health technology and the seed must be treated at pre-basic and basic level for control of plant-diseases, under strict seed health certification and production programme of the country (Bhutta et al, 1992) . There is a need to test germ-plasm and other breeding materials before their exploitation in wheat breeding programme of the country. Some seed-borne fungi considered to be saprophytes, such as *Alternaria tenuis., Aspergillus spp., Bipolaris hawaiiensis, Cladosporium spp., Epicocum spp., Penicillium spp.* and *Rhizopus spp.,* were also recorded but not counted.

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FEASIBILITY OF SILVO-PASTORAL MODEL FOR SALINE - SODIC SOILS IN ARID CLIMATE

*Ghulam Akbar**

ABSTRACT

A study was conducted at Arid Zone Research Station (P ARC), Bahawalpur, during 1991-92 on saline-sodic soils, in order to bring these areas under economic productivity and to overcome the deticiency of forage and fuelwood. Eighteen strips, each measuring 8mx 25m, were planted with Kallar grass *(Leptochloa fusca).* Grass seedlings were planted at 0.5-m spacing. One-year old nursery-raised seedlings of six species of saltbush *(Atriplex lentiformis, A. halimus, A. amnicola,. A. nummularia., A. canescens. and A. stocksii)* were planted on raised beds (0.5 m high) in rows, along strips containing Kallar grass. The saltbush seedlings were planted in linear fashion at a spacing of 2.5 m. There were 10 seedlings of each saltbush species in a row, forming a replication. The study was replicated three times. Thus, there were 18 strips of Kallar grass having 30 seedlings of each of the six *Artiplex* species. Data on green biomass of Kallar Grass, survival percentage, crown diameter and height of the seedlings of each species of saltbush were recorded on six-monthly basis.

The results revealed that Atriplex halimus outperfomrd all the six species, in terms of survival, followed by A. conescens, A. amnicola, A. nummularia and A. lentiformis. Atriplex stocksii exhibited the lowest (4%) survival in this study. Maximum crown diameter was observed in case of A. canescens, followd by A. amnicola, A. nummularia and A. A. halimus. The seedlings of A. lentiformis and A. stocksii did nto survive in two replications. Kallar grass, on the average provided 20-tons/ha fresh matter yield on six-monthly basis. The study revealed that this type of landuse is highly suitable for areas infested with salinity/sodicity and where cereal crops cannot be grown. Moreover, this study also exhibited that forage and fueldwood demand can successfully be met by bringing such problem-areas under suitable silvo-pastoral system.

INTRODUCTION

About 20 million hectare (m. ha) of the total area of Pakistan is under cultivation. Almost 16.2 m ha of the cultivated area is irrigated, of which canals irrigate 11.4 m. ha and the rest is irrigated either by tubewellsor other means. Salt-affected area is about 6.3 m. ha, which is mainly confined to the irrigated parts of the Indus plain (Qureshi *et at.* 1996). These areas have serious socio- economic implications and mostly concerns subsistence farmers. Although occurring in patches. These soils have combined salinity, sodicity problems (Aslam et al. 1991; Qureshi and Barrett-Lennard. 1998). Saline sodic soils are generally regarded as wastelands and such areas play no significant role in the national economy. These soils could be reclaimed,either by use of gypsum or through raising salt-tolerant plants. Biological approaches improve soil-structure by adding organic matter and acidifying the soil that makes soluble calcium available. Continuous raising of kallar grass *(Leptochloa fusca)* on such soils is widely practiced by the farmers (Qureshi and Barrett-Lennard, 1998).

Livestock is an integral part of the agriculture in Pakistan and hence fodder-shortage is a common problem when we try to raise good-quality animals. Apart from fodder-shortage, household energy requirements in the rural setup are met mainly from the trees grown on agricultural lands. Having this scenario in mind, a study was underaken to evaluate the potential of salt-tolerant shrubs and grass species under saline sodic conditions, to meet the forage and fuelwood needs from the areas regarded as waste-lands. The ultimate aim of this study was to explore the possibilities of bringing saline sodic soils under productive use.

STUDY SITE

The study was conducted at Arid Zone Research Station of Pakistan Agricultural Research .Council at Bahawalpur. Bahawalpur lies in the southern part of Punjab province, at about 29° 24' N latitude and longitude 710 47' E,at an elevation of about 116 m above mean sea level (FAO 1993). The soils are generally clay loam (clay 43%, silt 36% and sand 21%). Irrigation to the study-area was provided through tubewell, whose water, like 70% of the tubewells in

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Indus basin (Qureshi and Barret-Lennard 1998), is marginally fit for cultivation (1300 mmohs) (AZRI 1996). Other chemical characteristics of the study-soil include pH 8.9, ECe 10.8 dS/m-l, and SAR 28.

Bahawalpur, being on the immediate verge of Cholistan desert, experiences hot tropical climate (Table 1). Maximum temperature during summer may reach up to 50 °C, while the minimum temperature seldom drops below zero. Most of the precipitation is received during monsoon period, extending from July through mid-September (FAO, 1993). Evaporation exceeds precipitation in each month considerably. Climate data, based on 30 years average (FAO, 1993), is presented in Table 1.

MATERIALS AND METHODS

During the month of August, 1991, eighteen strips, each measuring 8m x 25m, were planted with Kallar grass (*Leptochloa fusca*). Grass seedlings were planted at 0.5-m spacing. One-year old nursery-raised seedlings of six species of saltbushes (*Atriplex lentiformis, A. halimus, A. ammnicola, A. mammularia., A. canescens and A. stocksii*) were planted on raised beds (0.5 m high) in rows, along stirps containing Kallar grass. The saltbush seedlings were planted in linear fashion ata spacing of 2.5-m. There were 10 seedlings of each saltubsuh species in a row, forming a replication. The study was replicated three times. Thus, there were 18 strips of Kallar grass having 30 seedlings of each of the six Atriplex species. Data on green biomass of Kallar grass. survival percentage, crown diameter and height of the seedlings of each saltbush species, were recorded on six-monthly bases. Samples of green biomass fo kallar grass were oven-dried for 48 hours at 60 ^{o}C and dry-matter yeild (DMY) was worked out. Irrigation was provided to the study area, except for rainy days, on weekly basis during summer (April - September) and on monthly basis during winter (October - March). The data were analyzed using Randomized Complete Block Design and means were separated using Duncan's multiple range test (Gomez and Gomez 1984).

RESULTS

Saltbush Species: Final measurements, as in September 1994, regarding growth-rate (height and crown diameter) and survival of all the saltbush species are presented in Table 2 and Figure 1 below.

The results (Table 2) indicate that, in case of plant height, A. amnicola outperformed numerically all the saltbush species tested in this study; however, its height was significantly ($p<0.05$) greater than A. canescens and A. stocksii. Both the latter species did not differ significantly ($p<0.05$) from Atriplex lentiformis, A. nummulari and A. halimus. The crown diameter among all the species did not differ significantly *($p<0.05$).* Numerically, *Atriplex canescens* attained more crown-spread), followed by *A. amnicola, A. nummularia, A. halimus, A, lentiformis* and finally A. stocksii. Crown diameters of all the saltbush species raised in this study were higher, compared to their respective vertical growth.

The plants of *A, halimus* exhibited 100% survival-rate followed by *A. canescens, A. amnicola, A. mummularia, A. lentiformis and A, stocks ii,* Thus, the results revealed that *A, stocksii* is poor performer in terms of growth-rate as well as plant-survival among all the six saltbush species planted in this study. All other species did well in hot climatic and saline sodic conditions of Bahawalpur.

Kallar Grass: Dry matter yield (DMY) of kallar grass increased progressively with the time from initial establishment (Fig. 2). The lowest DMY was recorded six mmonths after the initiation of the study (April 1992) that did not differ significantly ($p<0.05$) from that one year after planting (September 1992), but it differed significantly ($p<0.05$) as the time increased from one year after planting onward. However, the DMY was not significantly different ($p<0.05$) among the last two cuttings (April and September 1994) of the study, showing that the grass had increased potential of adding biomass with the passage of time, This also provided the evidence that soil-conditions had also improved over time. The earlier reduction in the yield was probably the initial growth-development of the plants and their adjustment with the soil conditions.

DISCUSSION

The study-site of Bahawalpur is a representative hot area of the Indus plain, where salinity-sodicity is a wide-spread problem. Accompanied to this, fuel wood and forage are also immediate requirements of the

Table – 1: Meteorological Data of Bahawalpur (30 Years Average) (1961 – 1990)

Month	Mean Monthly Temp		Rainfall	Mean R.H.	PE (Max)	Wind
	Min	Max	mm	(%)	(mm)	(Knots)
	°C					
Jan.	2.0	26.0	5.9	68	65.3	2.9
Feb.	3.5	29.5	11.1	64	77.8	3.4
Mar.	8.1	36.6	9.2	60	103.2	3.8
April	14.1	42.4	7.1	47	133.4	3.8
May	19.1	45.1	6.1	40	156.5	4.8
June	23.5	45.8	16.4	48	169.4	5.7
July	24.0	43.5	51.3	61	163.2	4.5
Aug.	24.6	41.2	42.1	65	159.9	4.7
Sept.	21.2	39.7	11.6	64	145.9	4.1
Oct.	13.6	38.3	0.6	60	127.7	3.3
Nov.	7.2	34.0	4.2	65	98.4	2.0
Dec.	3.0	28.2	3.0	69	71.5	2.2
Year (Mean)	13.7	37.4	168.6 (Total)	59	147.2	3.6

R.H.=Relative Humidity, PE = Potential Evaporjation

Table – 2: Height and crown diameter of different *Atriplex* species grown in saline-sodic soil (cm)

S.No.		Height	Crown diameter
1.	*A. lentiformis*	66ab	80a
2.	*A. conescens*	41b	239a
3.	*A. amnicola*	145a	225a
4.	*A. nummularia*	125ab	219a
5.	*A. stocksii*	32b	67a
6.	*A. halimus*	119ab	193a

Figures with the same superscripts in the same column do not differ significantly ($p<0.05$), LSD=94 & 182 for height and dia., respectively

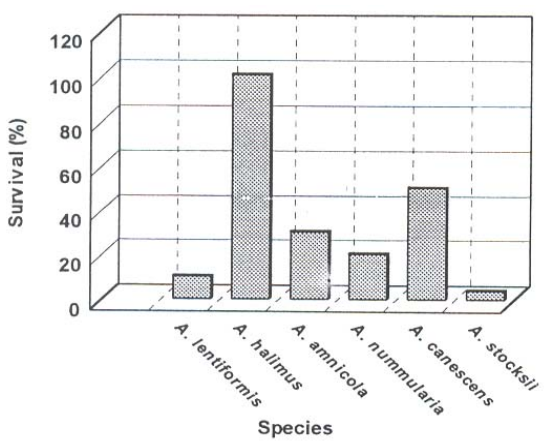
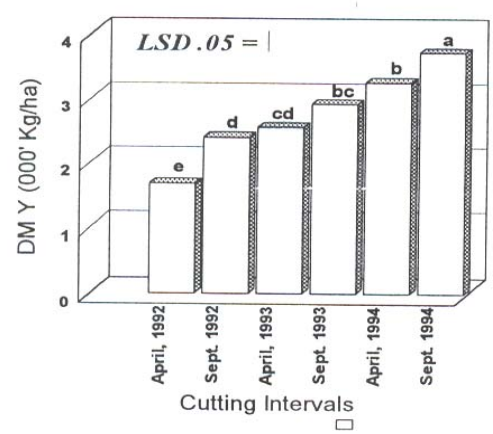


Figure - 1: Survival performance of Saltbush species in saline sodic soil



Note: Bars carrying similar alphabets do not differ significantly at P≤0.05

Figure - 2: Dry matter yield of Kallar grass at different cutting intervals

subsistence farmers. The Artip*lex* species that are commonly known as salt bushes, perform well in such *hot* places and are highly suited in agroforestly land-use for saline areas. These species provide nutritious forage *to* the livestock, particularly small ruminants year round, in areas where availability of good-quality forage is a serious problem, since livestock in general meets half of its feed-requirements from crop-residues and one-third from grazing (Sandhu 1988; Hanjra and Rasool 1991; Barrett-Lennard and Galloway, 1996).

Saltbushes comprise almost 200 species, thus exhibiting high genetic diversity (Hanjra and Rasool 1991) These species adapt well, not only to the dry areas, but also irrigated areas where salinity is a serious problem. Thus, saltbushes have enormous potential to foster plant, soil and livestock productivity. Hanjra and Rasool (1991) reported that saltbushes have been regarded as nutritious forage-plants (organic matter 73%, crude protein 19%, crude fiber 24% and digestibility of crude protein 79%). In feeding trials, sheep not only increased its intake but also gained slight weight when fed solely on saltbush (A. *canescens)* (Rehman *et al.* 1988; 1991).

The potential of using halophytes like saltbushes on salt-affected soils can bridge the gap of forage-supply during critical periods. Apart from meeting forage and fuel-wood requirements of the small farmers, saltbushes provide a less expensive option for biological amelioration of problem-soils. Such land-use practices increase the income of subsistence farmers from areas lying unproductive otherwise. Saltbushes are capable of growing under various soil and climatic conditions and have the characteristic of drought-resistance and can tolerate salinity, both in soil and water.

Ahmad (1989) reported the results of study conducted at sandy coast. Eleven saltbush species were initially sown in this study, but only eight species germinated under prevailing condicitons while the remaining three (*viz.*, *A. bunburyana, A. semibaccata and A. canescens*) failed to do so. These eight species were studed under field conditions. the plants were irrigated with undergorund saline water (EC. varying from 10-17 dS/m^{-1}; SAR varying from 25-30). Data on biomass-production of thse species revelaed that A. amnicola outperfomred in yeild of biomass, followed by A. *isatidea, A. cinerea, A. lentiformis, A. halimus, A. nummularia, A. paludosa and A. undulata*. However, the author mentioned that A. halimus was found to be the most drought-tolerant our of all the Atriplex species tested in the study. Abdullah et al. (1991) ranked the saltbush species in descending order, based on survival, height, volume and biomass as A. lentiformis. A. bunburyana, A. halimus, A. undulata, A. amnicola and A. cinerera. The authors, while reporting the results of a study conducted in Dingarh (Cholistan desert, Bahawalpur) concluded that *A. lentiformis, A. bunburyana, A. halimus and A. amnicola 949* are the most prominent species that could be raised by using saline water. Similarly, *A. lentiformis, A. ammnicola, and A. halimus* have exhibited the best growth in saline sodic soils of Peshawar valley (Rashid et al. 1991).

Aslam et al. (1991) mentioned that salt-affected soils could be effectively used for the production fo Kallar grass during summer, provided sufficient irrigation-water is available. The autors mentioned that by raising Kallar grass, soil-properties are also improved beside a net income to the farmer at Rs. 1400/- per acre. Kallar grass is widely planted by the irrigated farmers in areas having problems of salinity and it is primarily used as a potential forage for cattle and buffaloes. The biomass produced by this grass can also be used as a substratum for mushroom and enerlgy production (Aslam et al., 1991).

Malik et al (1986) reported that ,among many plants collected in the country (by Nuclear Institute for Agriculture and Biology (NIAB)) for testing them for the levels of their salt-tolerance, the Kallar grass was found to be the most salt-tolerant. The grass can survive at very high salinities (40 ds m^{-1}). However, it remains economical upto a salinity-level of 22 ds mol, which is quite a high salinity indeed. The grass was also grown in fields and it was noticed that it grew, year after year ,without any fertilizer but there was no loss of yield. It was also found that grass fixes biological nitrogen through free living nitrogen-fixing bacteria in the soil. The authors mentioned that the grass is perennial and can be propagated vegetatively through its cuttings. It can grow to a height of 4-5 feet and can provide four cuttings, to give 40 tons of biomass per ha) per year. The grass has been used as fodder for the buffaloes, without any apparent adverse eftects. It has also been used as green manure and as feed-stock for a pilot biogas plant. It has successfully been used for making pulp and as

substrata for raising mushrooms and even for saccharification of celluosic materials and their one-stage conversion into alcohol.

Singh et al. (1988) discussed the forage production, chemical composition and nutrient cycling fo karnal grass (*Leptochloa fusca*) planted with mesquite (*Prosopis juliflora*) in a unified agroforestry system, on an extrely sodic soil lying barren in Karnal district of India. Karnal grass gave 25.3 t/ha green-forage yield in 8 cuts, in a period of 26 months proving its great potential as a fodder crop. The mean N, P, K, Ca, Mg, S and Na contents in the whole plant was 1.36, 0.20,0.65,0.19, 1.54 and 1.52 percent in first cut, and 0.92,0.18,0.74,0.34,0.68,0.14 and 0.64 percent in the last cut, respectively. Increased content of the Ca and K decreased the Na concentration with subsequent cuttings and made this grass a valuable fodder under sodic soil conditions. Total nutrient removed was 567 kg/ha, within a period of little more than two years. It was interesting to note that this grass biologically pumped out 114-kg/ha sodium through the aerial biomass, thus acting as a trigger for the start of a plant-succession for the reclamation of sodic soils lying unproductive.

CONCLUSION

Silvo-pastoral land-use model discussed above needs to be established in the arid hot climate of the country, where salinity and sodicity are serious problems. However, the present study did not fully determine the extent of soil-improvement with this model and the economics of such land-use, if adopted by a small farmer. These questions need to be carefully addressed in future in investigations.

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THE GROWTH OF TOMATO PLANTS IN DIFFERENT POTTING MIXES, UNDER GREENHOUSE CONDITIONS

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ABSTRACT

Tomato variety Money Maker special plants were grown in teh Greenhouse in pots, during August, 1997, at Lincoln University, Canterbury, New Zealand, in several different potting mixes; Pumice, Perlite, Fine peat, Course peat, Pine-bark compost, andf soil as a control. It was then tested for the vegetative growth perjforamnces. Teh highest number of leaves, leaf area, vegetative buds, plant height, stem diameter, shoot and root dry-weight plant-1 were found in Pine bark compost, which were 43, 1592 cm2, 10,27cm, 1 cm, 6 g, and 0 g, respectivley, while the same parameters were found least in soil, which were 15.00, 626.74 cm2, 7.17, 14.82 cm, 0.67 cm, 1.69 g and 0.19g, respectivley. None of the mixes affected root-length. Almost all plants showed maximum vegetative growth in Pine-bark compost.

INTRODUCTION

The growth and production of tomtoes is now based almost entirely on artifical potting-mixes or substrates, rather than soil which was the common practive about fifteen years ago (Wilson, 1986). In some advanced countries, sterilized soils were used as a medium for plants in teh grenehouses, but this practive was very expensive and also there was a the lack fo good soil avialability. Teh potting mixes or aritficial substrates like peat, bark, vermiculite, rockwool and perlite, etc., have the following advantages i.e., disease and weed-free, light in weight, respeive meixes having the same composition, quicker growth and higher yields; so, tomato yields have increased three times more int he last rhity years, mainly due to monocropping systems and growing out of the soil (Silson, 1986).

In advanced countries, different kinds of potting-mixes are available, each of which has its own physical and chemical properties. The present experiment was performed in uniform environmental condiction in a glass house. The potting-mixes available int eh open market of New Zealand are; Pumice, Perlite, Fine peat, Coarse peat, and Pine-bark compost, etc., and so these were used.

MATERIALS AND METHODS

The experiment was laid out in the Greenhouse on 6th August, 1997, which is the normal cropping season in Lincoln University, Canterbury, New Zealand. Six treatments (potting-mixes) were used, i.e. soil (as a control), Pumice, Perlite, Fine peat, Coarse peat, or Pine-bark compost. Each potting-medium was repeated six times (6 replications) and laid in a randomized complete block design. At the initial set up of the experiemnt, three seedlings (50 days ol) were trnasplanted into pots having a diameter of 15 cm, on 6th August 1997. The seed were sown on the media having Clay, Silt and Organic matter with 1:1:1 ratios. The germination fo the seed took 15 days, and the germination was 98 percent. The cultivar chosen for the experiment was “Money-Maker Special’; this is one of the commercial greenhouse varieties grown successfully in New Zealand. Five days after transplanting, sorting was done and only one plant pot-I was left. Slow-release fertilizers were applied to all treatments, as a constant dose i.e. Osmocote was applied at the rate of 24g per 12 liters of media, which contains Nitrogen (N), Phosphorus (P_2O_5) and Potassium (K_2O), in the ratios of 15:4.8:18.8, respectively; Dolomite at 48g per 12 liters of media which contains Calcium and Magnesium. The main reason for using dolomite is to keep the pH level up, and other cultural practices (such as irrigation, weeding, etc) were maintained uniformly. The following data were recorded five weeks after the transplantation of seedlings: Plant height (cm), Leaf number plant-1, Leaf area in cm2, by using Li-Cor model 3100 area meter, Number of all vegetative buds, stem diameter (cm), root-growth (cm) and dry-weight of shoots and roots; by putting them in an oven at 70°C for 48 hours. The reproductive growth data was not recorded.

RESULTS

The mean maximum 27.2 cm plant height was found in pine-bark compost, which is significantly greater ($p<0.05$) than all other potting mixes. The mean minimum 14.8 cm plant height occurred in soil and was significantly different from all other potting mixes.

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Pumice produced plants with an average height of 22.79 cm, which was only significnalty different from pine-bark compost, but was statistically same as with perlite, fine epat and course peat, which were 24.5, 23.7 cm, respectivley. Plant height in perlite was not different fromt he fien peat, course peat and pien bark compost, while fine peat was highly differnt from compost, but not from course peat (Fig.1).

Number of leaves plant-I was significantly different ($p<0.05$) among different treatments. The maximum mean 43.83 leaves were observed in pine-bark compost, while minimum average 15:00 leaves-plant were found in soil media, which was significantly less as compared to pumice, perlite, fine peat, course peat and compost, which were 32.83, 37.67, 36.67, 41.83 and 43.83 plant^{-1}, respectively. Number of leaves in the pumice was not significantly different from course peat and compost, while leaves in perlite, fine peat, course peat and pine-bark compost were not significantly different (Fig., 2).

The mean number of vegetative buds plant-1 were significantly differetn at ($p<0.05$). The mean minimum 7.17 vegetative buds plant-1 were found in soil, which was significantly less than pumice, perlite, fine peat, course peat and pine-bark compost, which were 10.5, 10.5,10.83,10.67 and 10.83, respectively. There were no significant differences observed among the other potting-mixes, except soil (Fig.3). The dimeters of the stem of plants in different potting mixes were found significantly different at ($p<0.05$). The mean maximum 1.05cm stem diameter was found in pine-bark compost potting-mix. Soil media showed the mean minimum stem diameter of 0.67 cm, as compred to pumice, perlite, fine peat, course peat and pine-bark compost, which were 0.80,0.90,0.90,0.86 and 1.05 cm plant-1, respectivley. Pumice showed 0.80 cm stem diameter, which was significantly different from soil and pine-bark compost i.e., 0.67 and 1.05 cm, respectively, but it was not significantly different from perlite, fine peat and ocurse peat, which were 0.90,0.90 and 0.86 cm, respectivley. Stem diameter in perlite was simialr to fine peat, and course peat, but significantly different from pine bark compost. Fine peat was not different from course peat, but was less than pine-bark compost. Course peat was found significantly less than pine bark compost (Fig., 4).

The mean maximum 1592.64 cm^2 leaf area was observed in pinooark compost potting mix, which was significantly different from all other potting mixes. The

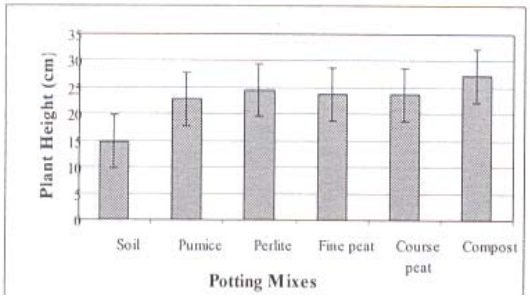

Figure - 1: Plant (Special Money Maker Tomato) height in different potting mixes

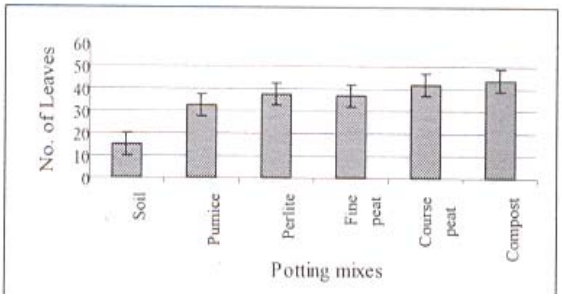

Figure - 2: No. of leaves per plant (Special Money Maker variety of tomato) in different potting mixes

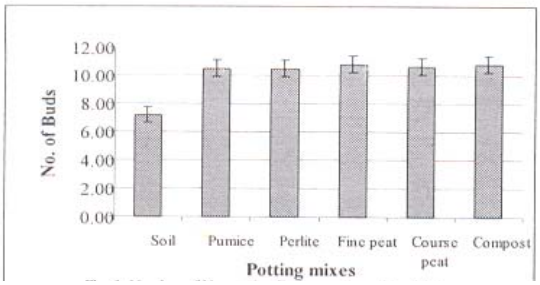

Figure - 3: Number of vegetative buds per plant (Special Money Mker Tomato) in different potting mixes)

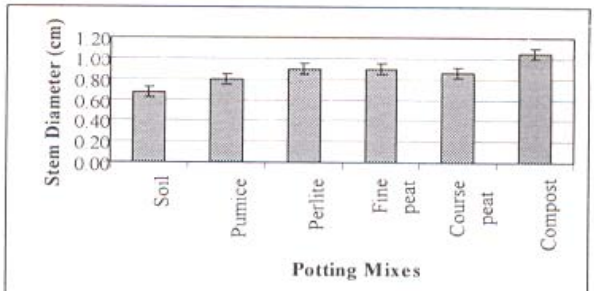

Figure - 4: Stem diameter of plant (Special Money Maker variety of tomato) in different potting mixes

mean minimum 626.74 cm^2 leaf area was observed in soil media, which was significantly less than pumice, perlite, fine peat, course peat and pine bark compost, which were 1045.38,1338.00,1393.73, 1319.17, and 1592.64 cm^2, respectively. Pumice showed 1045.38 cm^2 leaf area, which was significantly less that fine peat, and pine-bark compost i.e., 1393.73 and 1592.64 cm2, respectively. There was statistically no difference found between pumice and course peat, which were *1045.38* and 1319.17 cm^2, respectively. There were also no significant differences in leaf-area found am,ong perlite, fine peat, course peat and pine-bark compost (Fig., 5).

Fresh weight of shoot and root were significantly maximum in compost media, followed by perlite media, and minimum shoot and fresh weight were obtained in soil or check media.(Fig., 6).

The mean maximum shoot dry weight, 6.33g, was found in pine-bark compost, while the mean minimum 1.69 shoot dry-weight plant-1 was found in soil media, which was significantly differnet from all potting mixes i.e., pumice, perlite, fine peat, course epat and pine-bark compost, which were 4.11,5.81,4.8,4.28 and 6.33g, respectively. Pumice showed no significant differences in leaf area from perlite fine peat and course peat, but was signifcantly different from pine-bark compost. Perlite showed no significant differences from fine peat, coarse peat and pine-bark compost. Similarly, fine peat showed no significant differnces from course peat and pine-bark compost, but course peat showed less dry weight than pine bark compost (Fig.7).

The mean maximum root dry weights 0.97 and 0.79g were shown by perlite and pine-bark compost, respectively, while the mean minimum 0.19g root dry weight was shown by soil media, that was significantly less than perlite, fine peat, and pine-bark compost, which were 0.97, 0.64 and 0.79g, respectively, but was not different from pumice and course peat i.e. 0.50 and 0.45g, respectively. Pumice showed less root dry-weight only significantly different from perlite, but not from the other potting mixes. Perlite was significantly different in root dry-weight production from course peat. There were no significant differences in root dry-weight among fine peat, course peat and pine bark compost (Fig., 7).

It is observed in this project that the fresh weight was directly proportional to dry weight in both shoot and root in all the tested media. Moreover, there was no significant root-length difference among different potting mixes.

DISCUSSION

The best plant-height, vegetative buds, number of leaves, leaf-area, stem diameter, shoot and root dry-weight $plant^{-1}$ occurred in pine-bark compost, which may be because this potting mix has a large capacity to keep water and contains more organic matter than the other potting mixes. Nogales, et at (1984) reported that tomato is the most sensitive to compost-addition, showing 10% germination with 10% compost addition. They further reported that in pots, the application of 60 t/ha of compost to soil, with or without N, P, K, S, Ca and Mg fertilizers, promoted the growth of ryegrass. In the compost, the microorganisms' activities in the plant-remains produce heat and transform complex organic materials into forms, which are, later on available to roots. Bark also open up the soil and peat improves aeration and water-holding capacity (Hessayon, 1986). Bark has given good yields of tomatoes, provided proper attention is paid to nitrogenous fertilizing and iron-additions *to* counteract high manganese levels (Wilson, 1983), Solbrae, 1975, 1976). The finding that the poorest plant-growth was observed in soil media, which had the low capacity to keep water and was compact, as compared to other potting mixes. It is because there are some disadvantages of soil, for example it has disease and weeds which should be sterilized before use (Wilson, 1984). Sowan *et al* (1986) also reported that the plant-performance in rice hulls, sand and peat was higher than that of control substrate, which was soil.

Dry weight of shoot and root were both found maximum in pine-bark compost and perlite. Perlite potting-mix is also an ideal rooting medium; it is sterile, chemically inert, physically stable, drains easily, yet has a good capillary action, so it has the ideal physical characteristics especially as regards air and water capacities (Wilson 1984). It was also observed that shoot and root dry-weight in fine peat and course peat was significantly lower than pine-bark compost. Organic potting -mixes or substrates also vary in their physio-chemical properties. Starck and Okruszko (1984) reported that total yield was high in pine bark and peat than that for sawdust. The organic potting-mixes like pine-bark compost, fine peat and course peat.used in this experiment had the following characteristics;

	pH	Nitrate nitrogen	Conductivity
Pine bark compost	5.0	19.0 (ppm)	0.04 (mS/cm)
Fine peat	3.9	03.0 (ppm)	56.4 (mS/cm)
Course peat	4.2	<1.0 (ppm)	0.08 (mS/cm)

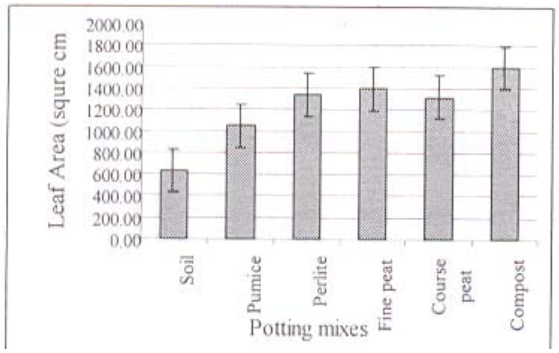

Figure - 5: Leaf Area per plant (Special Money Maker variety of tomato) in different potting mixes)

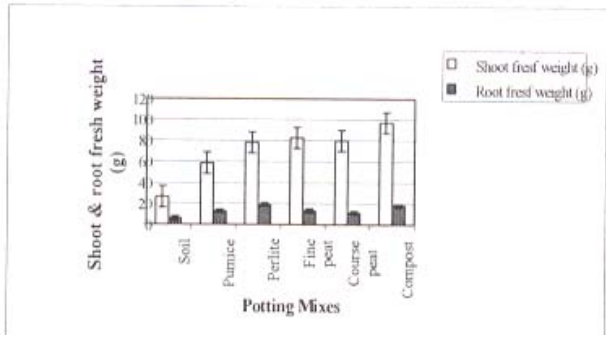

Figure - 6: Fresh weight of shoot and root of Special Money Maker variety of tomato in different potting mixes

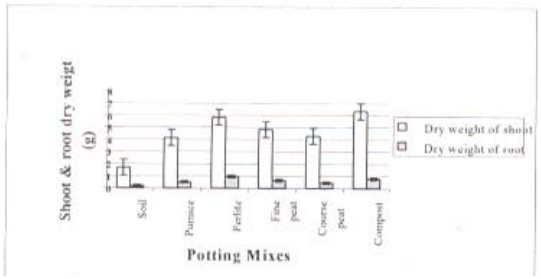

Figure - 7: Dry weight of shoot and root of Special Money Maker variety of tomato in different potting mixes

(These were the recommended analyses provided by the manufacturing companies). So, due to these differences among the potting mixes, it may be readily understand that pine-bark compost showed high shoot and root dry-weight plant^{-1}. Similar trend was noticed in shoot and root fresh-weight. It is observed in this project that the fresh wegith is directly proportional to dry weight, in both shoot and root, in all the tested media.

All potting mixes other than pine-bark compost also showed some signfiicant differences among themselves, but mostly they showed less effect on different vegetative growth parameters.

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