

Development of healthy rice seedlings: A practical application of soil solarization

Banu SP¹, Abawi GS², Duxbury JM², Lauren JG², Meisner CA²

¹ Research Wing, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh

² 2917 Bradfield Hall, Cornell University, Ithaca, New York 14853 USA

Email: salinapbanu@yahoo.com

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Introduction

Continuous cropping systems (rice-wheat) and mono-culture (rice-rice-rice) practices develop soil sickness in Bangladesh, a traditional rice growing country. Soil-borne pests have undoubtedly proliferated under this cropping system and have become a major cause of reduced productivity and system sustainability. Although considerable effort has been devoted to the management of major foliar pests, the diagnosis and impact of the soil pest complex, especially root pathogens, has not been adequately investigated (Dubin & Bimb, 1994). Of these soil-borne pests include *Bipolaris*, *Fusarium*, *Sclerotium*, and nematodes, which cause symptoms such as poor stand establishment and small, shallow root systems.

Poor soil physical condition and nutrient deficiencies are also important constraints on crop productivity and vulnerability to soil-borne pests. The poor soil biological health and increased demand of fertilizer are issues for low crop productivity in Bangladesh. These fundamental constraints undoubtedly limit the effectiveness of other yield enhancing technologies. Few appropriate technologies are available for resource-poor farmers to address these problems. Soil solarization is one technology that has been trialled for the biological control of soil-borne pathogens and to enhance agricultural productivity (DeVay and Katan 1991). It leaves no toxic/chemical residues and can be used easily. Soil solarization also improves soil structure and increases the availability of nitrogen (N) and other essential plant nutrients (Elmore *et al.*, 1997), which leads to increased plant health/growth and reduced fertilization requirements. Solarization is a natural, hydrothermal process accomplished by passive capture of solar radiation in moist soil covered with transparent polythene film. Transparent film allows passage of solar energy into the soil, where is converted into longer wavelength infrared energy. This long wave energy is trapped beneath the film, creating a green house effect (Stapleton, 2000). For mesophilic organisms in soil (most plant pathogens, weeds and other pests), a temperature threshold of about 37⁰C or above is critical for temperature to be lethal (DeVay and Katan 1991). Pest organisms may be killed or weakened by lethal heat ($\geq 37^{\circ}\text{C}$) to the extent that they are unable to cause damage to plants/or they are more susceptible to chemical toxicants (Chauhan *et al.*, 1988; Stapleton, 1997).

This technique can be applied manually or by machines, so it is suitable for both developing and developed countries. It is recommended that the field be solarized just before a cash-crop is grown so that it can benefit from the treatment in the rotation cycle for control of soil-borne pathogens including *Bipolaris*, *Fusarium*, *Sclerotium* and root-knot nematodes. Then, after the reduction of the pathogenic populations, the land is left for three or four succeeding crops and then solarized again prior to planting the same cash-crop. The objectives of this investigation were to assess whether root/soil health can be improved through controlling soil-borne pests and increasing nutrient availability at rice nurseries through soil solarization.

Material and Methods

A single layer of transparent polyethylene sheet was laid on the nursery bed for four weeks during summer (April-May). Light irrigation was applied prior to the placement of polyethylene sheets to

obtain effective pathogen control (by stimulating microorganisms to break dormancy and then to be killed by heat) and to improve heat conductance in soil (Fig. 1). Paired solarized and unsolarized plots were established on farmer's fields and experimental stations for diagnostic and demonstration trials. Rice seedlings were raised in solarized and unsolarized nurseries and then transplanted into unsolarized main fields. Agronomic factors including rice seedling emergence, seedling height, yield, incidence of black seed and unfertile seed sites, and chlorophyll content on leaf (by SPAD meter) were measured. Likewise pathological factors were assessed. Root health was evaluated visually at maximum tillering utilizing a rating scale of 1 (healthy roots, no visible disease symptoms) to 9 (greater than 75% of root tissue are diseased, reduced in size and with advanced signs of decay) (CIAT 1987). Root knot nematode (*Meloidogyne graminicola*) galls were counted from randomly selected plants. Soils were collected from 0-10 cm for analysis of inorganic nitrogen (2M KCl extractable), available micronutrients (DTPA extractable) and temperature was taken daily at 1.00pm at 10cm depth. Rice yields from each treatment were determined by destructive harvest from one square meter plots, and yields were adjusted to 12% moisture content.

Results and Discussion

The increase in soil temperature over control was 5-10°C, the highest temperature being 52°C which was within the lethal range for soil-borne pests (DeVay and Katan 1991, Stapleton, 1997). The results indicated that the solarization of rice seedling nurseries is a simple, low-cost, non-chemical soil treatment method to produce nematode- and pathogen- free, vigorous "healthy rice seedlings" (Fig. 2) (Parvin *et al.*, 1998, Stapleton 2000). The inorganic soil nitrogen was found to increase by a factor of 1.7-2.4 and available manganese by 3.8 times after solarization. These results are consistent with those reported by Elmore (1995), Chen and Katan (1980) and Stapleton *et al.*, (1985). Solarization had beneficial effects on plant establishment and early growth (Fig. 3). Chlorophyll content and seedling height were increased by 11.6% and 10.8% respectively in unfertilized solarized seedbed over the non-solarized. Measurements of pathogen effects showed substantial differences between solarized and unsolarized treatments. Severity of nematode gall counts on rice roots were consistently less in solarized treatments compared to unsolarized treatments (Fig. 4). Healthy seedling roots were bigger, lighter in color and had less pathogen damage, which had good root grading (i.e. healthy root system) in the main field (Fig. 5). This indicates improvement of root health. Healthy seedlings exhibited more vigorous growth as exemplified by a darker green color and taller plants. With the healthy start that rice seedlings get in solarized nurseries, transplants appear to have a greater capacity to withstand soil-borne biological stresses.

Yield increase in response to solarization was 18% at farm level in Gazipur and 42% in Dinajpur district. Reduction in incidence of black and infertile seed sites in the panicle was 38% and 12% respectively. The long-term positive effects of single soil solarization in summer was identified for three succeeding crops (monsoon rice-wheat-spring rice) by reducing soil borne pests such as *Bipolaris* spp., *Curvularia* spp., *Fusarium* spp., *Sclerotium* spp., and nematodes. Increase of nitrogen mineralization reduced the top dressing of urea in the first crop monsoon rice after solarization. A single top dress of urea was given in monsoon rice instead of three. Thus, this study provided evidence that reduced use of chemical fertilizer (urea) is possible, and non-chemical soil treatment satisfactorily addresses soil-borne pest pressure.

A promotional package has been developed to disseminate the "Healthy Seedlings" technology. The "Healthy Seedlings" technology for rice was transferred to 3500 farm households in Bangladesh (Banu *et al.*, 2005). The reasonable success of this technology is shown by 67-71% adoption (2005 *Impact Statement* of Cornell University, USA) in Bangladesh. This technology would also be a good agriculture business, especially for marginal farmers. Farmer's received an additional gross return of about Tk.10,276/ha by investing only Tk.941/ha extra cost for solarization (Baksh *et al.*, 2004).

The development of “Healthy Seedlings” through soil solarization is a simple, effective and easily understandable agricultural practice for the resource-poor farmers of Bangladesh to improve their livelihoods and food security through increased productivity. Farmers themselves transfer the technology from one farmer to another as the method is very simple and in practice not costly.

Acknowledgements

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Figures and Tables

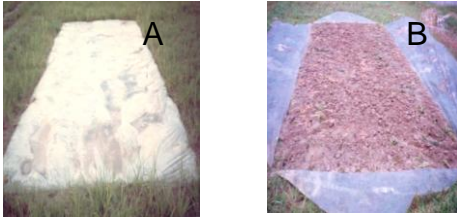


Fig. 1: Soil solarization completed (A) and opened (B) in preparation of seeding



Fig. 2: Healthy seedlings (right) with control (left) in farmers' field

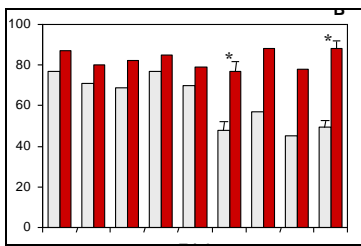


Fig. 3: Rice emergence (%) in 9 trials

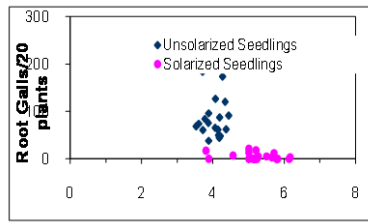


Fig 4: Effect of solarization on root-knot nematodes in 25 farms

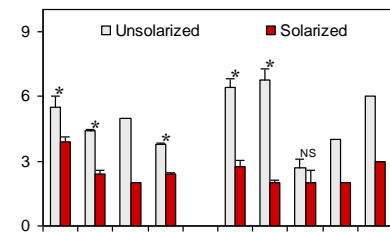


Fig. 5: Effect of solarization on root grading (1-9 scale) in 9 trials

Conservation agriculture: A dynamic approach for continuing biomass production under rain-fed conditions of the Mediterranean climate

Ben-Hammouda M¹, Nouiri I², Khelil A³, Talbi S⁴, Thabet B⁵

Benhammouda.moncef@iresa.agrinet.tn

¹ ESAK, Le Kef 7100; ^{2,5} INAT, Tunis 1002; ^{3,4} PADAC/ESAK, Le Kef 7100, Tunisia

Key words: relay cropping, continuing cropping, cereals, legumes, Tunisia.

Introduction

Under rain-fed conditions, farmers of the South Mediterranean experience difficulties in getting adequate economic returns with conventional agricultural techniques which require costly inputs for a relatively low and unstable yield of a (generally) single crop. Water resources are also becoming increasingly scarce and arable land is under continuous pressure from growing urbanization, leaving little room for farmers to adjust. Sarkiss et al. (1994) reported that rain-fall in the Tunisian climate is variable year-to-year, regardless of the agro-ecological zone, but this not the case for temperature. Rain variability within and between seasons can be observed within the same year, and Stewart (2007) showed that practices that work well one year may not work nearly as well in an the next. There is a growing need for a change in management of the soil-plant-atmosphere continuum, and conservation agriculture (CA) proposed since the 1970's as an alternative system of natural resource management has the potential to reduce production costs and crop yield variability, while offering the possibility of continuous biomass production under rain-fed conditions and improved water efficiency under irrigation.

Farmers need to adopt alternative techniques to better cope with climate variability by adapting crop rotations to varying season conditions, especially with regard to highly variable rainfall. They would therefore be no real purpose in adopting one crop sequence, such as cereal/legume. A farmer might instead grow silage, hay, grains, cover crop, 'catch' crop, or any suitable combination of thereof. This flexible mode of crop management would be better suited to cereal-legume/animal (sheep) based production systems, and this dynamic approach to crop production depends on appropriate agronomic sequencing (Ben-Hammouda et al., 2009) rather than a fixed rotation. Such systems need a comprehensive and integrative agro-climatic characterization of the environment, including periods of water deficits (Gardner et al., 1985), and active vegetative growth, probability of opening and late rains, monthly and seasonal rains, soil water dynamics, soil organic matter, etc. in relation to crop production requirements.

Material and Methods

Field experimentation was conducted on a loam soil (Donahue et al., 1983) in the Oued-Zergua/Beja-Governorate (Lat: 36°43'37.10"; Long: 9°27'09.33"). This is a semi-arid zone of Tunisia that receives an annual average rainfall of 363 mm with 26 % variability over the last 4 years (Figure 1). A monthly rain diagram was used to properly identify early and late rains, together with the growth cycle of crops, including potential legumes (Figure 2). Periods of potential active vegetative growth of grazing crops were determined using an ombro-thermic diagram (Dupont and Compère 1997). An equal mix of oat (*Avena sativa* L.) and fenugreek (*Trigonella foenum-graceum* L.) was sown Mid-October 2008 at a seeding rate of 100 kg/ha and harvested for silage in early April 2009. Immediately following silage harvest, lucerne (*Medicago sativa* L.) was sown at a seeding rate of 25 kg/ha. After an opening rain (35 mm) in September 2009, a 200 sheep flock grazed the field. In late-October 2009, bread wheat (*Triticum aestivum* L.) was sown into the lucerne residues at a seeding rate of 170 kg/ha. For a legume/legume relay cropping, lucerne was sown in late-March 2009 after 40 mm of rain on peas (*Pisum sativum* L.), grown from late-January/09 at 68 cm interrow spacing and 120 kg/ha seeding rate. Standard cultural practices for semi-arid production (weed/fungal disease

control, nitrogen and phosphorus application, insect/pest management, etc), were applied for all crop sequences in this CA package.

Results and Discussion

Since the 08/09 growing season, continuous and sometimes relay cropping of these cereal/legume and legume/legume systems has been successfully practiced in rain-fed conditions of this semi-arid climate. The mix of oat and fenugreek sown in Mid-October/08 was harvested as silage in early-April 2009, with a biomass yield of 12 t/ha. Lucerne which was sown the same day as silage harvest yielded 4 t/ha Late-July 2009. After an opening rain (35 mm) in September 2009, a 200 sheep flock grazed the field for 5 days for 2 h/day/ha, and taking advantage of an Early-October rain an additional 5 ha were cut before sowing bread-wheat. In late-October 2009, bread wheat sown on lucerne as a cover crop yielded 2.8 t/ha, 0.2 t/ha less than a 1 crop/year bread-wheat/bread-wheat CA rotation. Continuous biomass production of bread-wheat/lucerne system continues at the same rate for the 10/11 growing season. In legume/legume relay cropping, lucerne sown on peas yielded 6.0 t/ha in late-May 2009, and has been grazed with a 200 sheep flock for 5 days at 2 head/ha. A 3.7 t/ha additional biomass of lucerne was harvested following an early-fall of 40 mm rain in September 2009 at the start of a promising 09/10 cereal growing season. This legume/legume scenario is an important break from the typical one crop a year mode frequently encountered under rain-fed conditions in semi-arid regions.

The continuing cereal/legume or a relay cropping in the case of a legume/legume sequence were possible with the early and late rains of October and April-May, respectively (Figure 2). The accumulation of heat units also appeared to be well matched with the rainfall (Figure 3), making a continuous biomass production a reality for this farm system. These examples of dynamic agronomic sequencing are among much attempts to apply the opportunity cropping concept, properly developed and adjusted for the Mediterranean climate characteristics of Tunisia (Ben-Hammouda et al., 2009). This approach to increasing biomass production should encourage farmers to invest in CA farm research and the specialized equipment, particularly the no-till drill that could have many annual uses and pay off its cost much more rapidly than the conventional drill used in a one crop/year conventional agriculture system.

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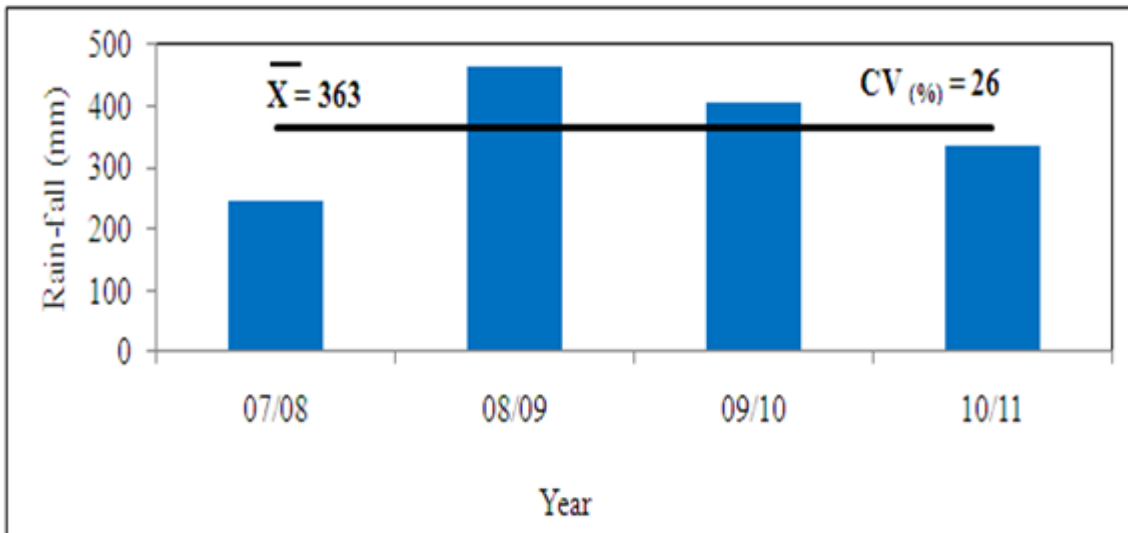


Figure 1. Yearly rain-fall for Oued-Zergua, over 4 growing seasons.

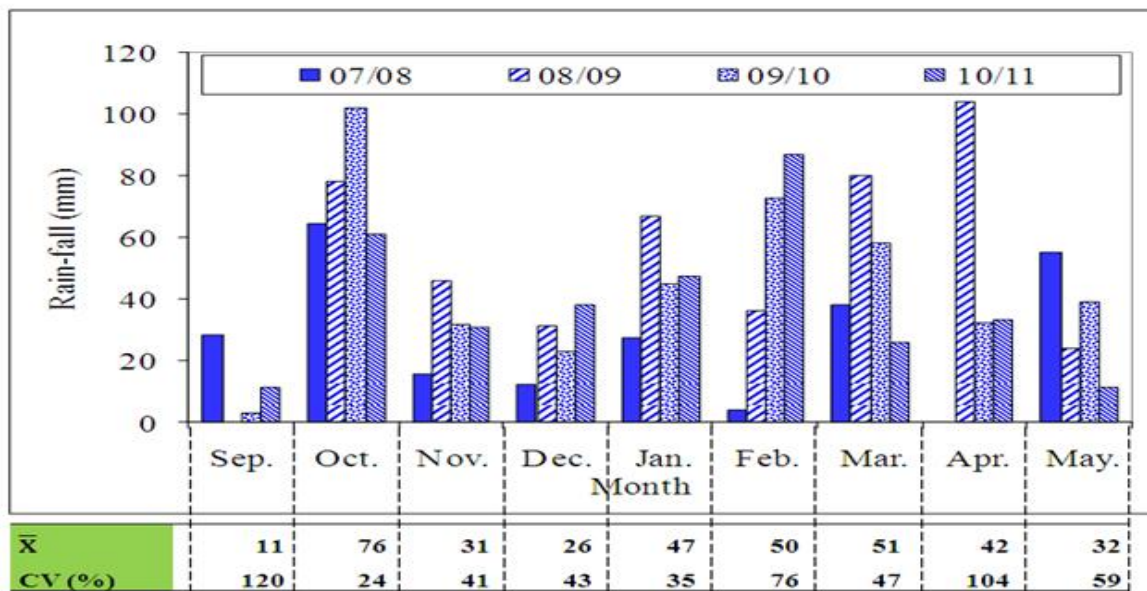


Figure 2. Monthly rain-fall for Oued-Zergua, over 4 growing seasons.

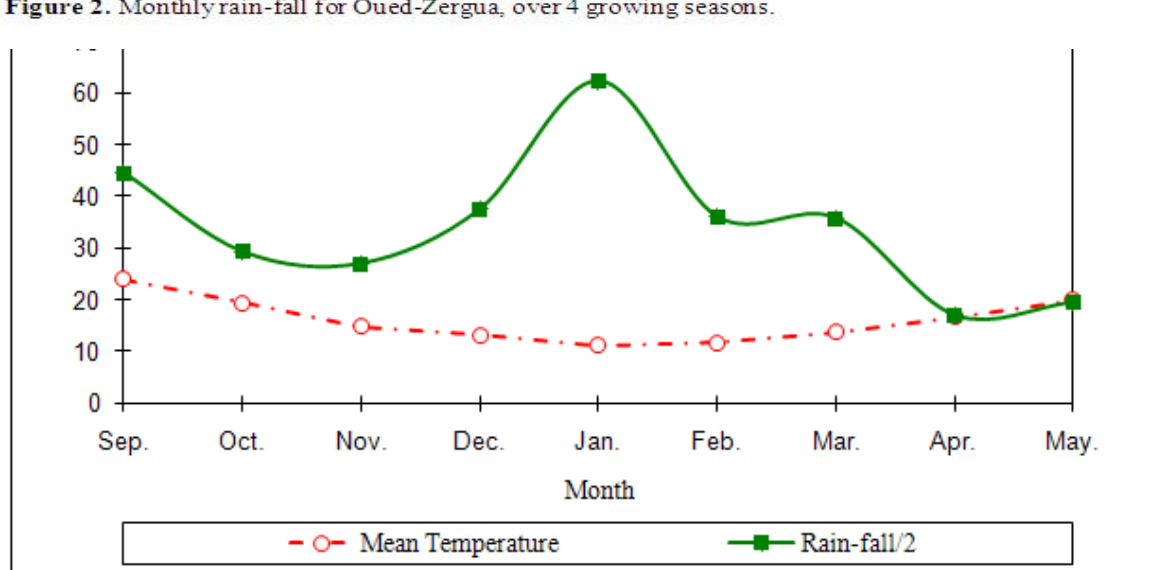


Figure 3. Ombrothermic diagram for Oued-Zergua, over 4 growing seasons.