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An Efficient Irrigation System for Plasticulture of Strawberry in Bangladesh

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Abstract

Plasticulture technique is a commonly used technique for advanced strawberry production. Due to high cost and tough maintenance, this technique is not practiced commercially in Bangladesh. We have found that, if the irrigation system can be switched to a cheaper one with high efficiency, then the cost can be minimized. We applied Micro-drip mediated irrigation system to minimize the cost. Our proposed modification of plasticulture using micro-drip irrigation system was outstanding in all our concerned horticultural parameters like height of the plants, number of leaves, north-south spreading, and east-west spreading of the plants. Paired Samples analysis between conventional and plasticulture procedure, test of significance for the pairs of mean, analysis of variance and LSD test at 5% level of significance were done for statistical analysis to conclude the result. The statistical analysis has also shown that the plasticulture method proposed by us was highly significant over the conventional technique and practical for the rural farmer of Bangladesh. It reduces the production costs, improves fruit quality and yield, and reduces the need for chemical pesticides.

Keywords: Micro drip irrigation, Soil solarization, Mulching, and Fruit Quality

1. Introduction

Strawberry is a perennial, stoloniferous herb belongs to the family Rosaceae, genus Fragaria and most widely consumed fruits throughout the world. It is one of the most popular fruits growing in the Northern hemisphere in temperate and sub temperate environment but is a newly introduced crop in Bangladesh. Strawberry is traditionally propagated vegetatively by rooted runners. To improve the quality of strawberry, conventional method is not suitable due to incidence of many diseases infection and environmental hazards, thus resulting in the gradual degeneration of cultivars performance in Bangladesh. The rate of strawberry propagation through conventional techniques is quite low and also difficult to maintain plant materials during summer. Moreover, the conventional way of production is not adequate to meet the commercial demand. Several improvements of the technology have been proposed by authors working with strawberry (Damiano, 1980; Drew et al.,1986; Swartz, 1987).

There is much interest in moving strawberry production systems in a more sustainable direction (Black et al., 2002a; Merwin and Pritts, 1993; Nonnecke and Dewitt, 1996;Pritts, 2002). Sustainable systems have been defined as systems that provide adequate quantity to meet demand, optimize crop output per unit of input, conserve and protect the essential agro–ecosystem resource base, and provide profits that are sufficient to support farmers and viable rural communities (Merwin and Pritts, 1993). For a system to be sustainable to the farmer, it has to be economically viable. Strawberry is a labor-intensive crop in which production of marketable fruit is closely tied to the ability of the grower to minimize weed, insect, and disease pressure through pesticide use and/or cultural practices (Chandler et al.,2001; Hancock et al., 2001; Rhainds et al.,2002), and a large amount of production costs are allocated to managing these pests. Weeds are a major management concern in strawberry and can severely limit the development of runners in matted row systems (Pritts and Kelly, 2001). Controlling weeds is especially vital during the establishment year (planting to first harvest) and between harvests in perennial plantings. Pathogens can cause substantial losses when outbreaks occur. In years when the weather is cool and wet from frequent rainfall, fruit rots can render much of the crop unmarketable and this problem is frequently faced by the farmers of Bangladesh in recent years. In other instances, virus and soil borne pathogens and pests can lead to plant growth decline and eventually death.

The growers and researchers in the mid-Atlantic and northeast regions of North America have long recognized inefficiencies in the conventional matted row production system and have searched for viable alternative production systems (Hancock et al. 1983, Black et al. 2002b). Some growers have experimented with a cold-climate plasticulture system that offers the benefits of better weed control, more efficient irrigation and fertilizer application, and larger and earlier-ripening fruit (O'Dell and Williams, 2000). The fate of pesticides is also of concern, particularly in early spring when pre-bloom fungicide sprays may coincide with heavy irrigation for frost protection. The planting is carried over for 3 to 7 years depending on disease pressure and other site specific considerations. Weed control in the conventional matted row system is accomplished through periodic mechanical cultivation with some hand weeding and possible herbicide application. Growers have long recognized in efficiencies in the matted row system and have explored other production practices to improve efficiency and reduce labor requirements (Hancock and Roueche, 1983; Rotthoff, 1980). One system currently being explored is a cold-climate adaptation of the annual hill or plasticulture system of California and Florida (Poling, 1996). This (Cold Climate Plasticulture) CCP system may offer some benefits in improved yields and fruit quality (Fiola et al., 1995, 1997; O'Dell and Williams, 2000). However, the tradeoff costs of this system include increased establishment costs and greater risk for crop loss resulting from spring frost. To offset these higher establishment costs and greater risk, the CCP system has relied on methyl bromide fumigation to maximize yields (Larson,1996; Pritts and Handley, 1998).With the phase out of methyl bromide, the potential yield benefits of the CCP system may be less pronounced(Hancock et al., 2001). The elimination of methyl bromide from strawberry production systems will undoubtedly result in increased need for other means to control weeds and diseases. Although exceptional weed control is achieved by the use of plastic mulch in the plasticulture system, herbicide application is necessary to control weeds between rows.

The objective of this study was to develop a farmer friendly cultivation system of strawberry. As a third world country Bangladeshi agriculture needs sustainable system of cultivation of sensitive crop like strawberry. Plasticulture system of strawberry production was outstanding according to reports all round the world. But in Bangladeshi perspective it's difficult for root level farmer to adopt such expensive system. We tried to reduce the cost of the system as well as to increase the efficiency of the system.

2. Materials and methods

The entire experiment was conducted in the village of Usmaninagar Thana named Thanagaon, in Sylhet district of Bangladesh.

2.1 Soil preparation & soil P^H

The experimental field was prepared by ploughing the land well and the soil P^H and solarization was done. The optimum Soil P^H (6.0-6.2) for strawberry cultivation was adjusted using dolomitic lime. The soil P^H 6.1 was reported prior to sowing the saplings in the field.

2.2 Soil solarization

Solarization of soil was done as described by Chen et al (1991) with some modifications. We covered the soil with black plastic in order to reduce the soil borne pathogen through passive capture of solar radiation, as a substitute of chemical fumigants.

2.3 Bed Preparation & mulching

Cultivation beds were prepared manually. The size and shape of each bed was 10-inch deep with 30 to 32 inches wide at the base and 26 to 28 inches wide on top to ensuring the slope. Black, thick (1.00-1.25 mm), long lasting and re-useable plastic mulch were manually installed to the prepared bed. The bed was checked for air tight quality, which was ensured by covering the mulch ends with mud.

2.4 Irrigation system

Conventional and micro drip adapter mediated irrigation systems were followed in our current investigation. The conventional irrigation was done by manual water sprayers while micro drip adapter mediated irrigation was adorned with saline bags (used) by removing thecanula (needle) and drip chamber from the bag. The bags with tube, micro drip adapter (controller), drip and dropper were thoroughly washed 3-5 times in detergents, slightly hot water and dried, in order to remove any uncertain chemicals. The upper portion of the bag was cut by a sharp knife smoothly to pour water into the bag for irrigation. Then one bag was hung beside each strawberry plantlet by a support and the tube was inserted into the plastic mulch and the controller remained outside the mulch. The micro drip adapter was manually switched to fully forcing mood.

2.5 Planting

For each experimental block 200 saplings were planted. The saplings were collected form Plant genetic engineering Lab. of Department of Genetic Engineering and Biotechnology, which were produced through tissue culture approach (Zobayer et al,2011). The plastic mulch were cut by a sharp knife in round shape (as smaller as possible) and the saplings were planted 18 inch apart from each other.

2.6 Statistical Analysis

SPSS 10.0 software was used for the analysis of experimental data. Paired sample analysis, Test of significance, ANOVA test and LSD (Latin Square Design) test were carried out the efficient process of strawberry cultivation.

3. Result & Discussion

The results revealed that micro-drip irrigation is the efficient technique of irrigation in the plasticulture technique of strawberry. The efficiency of micro-drip irrigation system was evaluated through statistical analysis. The height of the plants, number of leaves, north-south spreading, and east-west spreading of the plants were used as horticultural parameters. Paired Samples analysis between conventional and plasticulture procedure (table 1), test of significance for the pairs of mean (table 2), Analysis of variance (table 3) and LSD test at 5% level of significance (table 4) were done for statistical analysis. We have found micro-drip irrigation as a better irrigation process than that of conventional irrigation process as it showed more significant over conventional one in statistical analysis.

Soil disinfestations treatments, primarily utilizing biocidal chemicals or various forms of heat, are used by agricultural producers to reduce soil borne microbs of crop pests including fungal, bacterial, and nematode pathogens, weeds, and certain insects. These effects afford protection and stimulation of root growth and crop yield, and are often interrelated through complex mechanisms involving drastic qualitative and quantitative changes in the soil environment (Chen et al., 1991).Soil solarization is a soil heating and disinfection process that is accomplished through the passive capture of solar radiation in moist soil covered with clear plastic mulch. It is used as a substitute for chemical fumigants and its use is expected to increase as methyl bromide use is phased out. It is generally restricted to areas where air temperatures are very high during the summer and cropland is rotated out of production due to excessive heat. Soil solarization is compatible with other disinfection methods such as organic amendments (cruciferous crop residues, etc), biological control organisms or the use of pesticides. Research has shown that over 40 fungal pathogen, 25 species of nematodes, numerous weeds, and bacterial pathogen are also controlled or partially controlled with soil solarization (Katan, 1987; Stapleton and DeVay, 1995). Although the execution of solarization is simple, the overall mode of action can be complex, involving a combination of several interrelated processes which occur in treated soil and result in increased health, growth, yield, and quality of crop plants (Stapleton, 1997). In this particular experiment we solarized the soil for 15 days before planting by installing black plastic mulch in order to lessen the activity of pathogens.

Plastic mulches have been used commercially on vegetables since the early 1960s. Much of the early university research before 1960 was conducted on the impact of color (black or clear plastic film) on soil and air temperature, moisture retention and vegetable yields (Emmert, 1957). Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget (absorbitivity vs. reflectivity) of the surface and decreasing the soil water loss (Liakatas et al. 1986, Tanner, 1974). The color of mulch largely determines its energy-radiating behavior and its influence on the microclimate around a vegetable plant. Color affects the surface temperature of the mulch and the underlying soil temperature. Ham and Kluitenberg (1994) found that the degree of contact between the mulch and soil, often quantified as a thermal contact resistance, can affect greatly the performance of mulch. If an air space is created between the plastic mulch and the soil by a rough soil surface, soil warming can be less effective than expected. The soil temperature under a plastic mulch depends on the thermal properties (reflectivity, absorbitivity or transmittancy) of a particular material in relation to incoming solar radiation (Schales and Sheldrake 1963). Black plastic mulch, the predominate color used in vegetable production, is an opaque blackbody absorber and radiator. Black mulch absorbs most ultraviolet (UV) visible and infrared wavelengths of incoming solar radiation and re-radiates absorbed energy in the form of thermal radiation or long-wavelength infrared radiation. Much of the solar energy absorbed by black plastic mulch is lost to the atmosphere through radiation and forced convection. The efficiency with which black mulch increases soil temperature can be improved by optimizing conditions for transferring heat from the mulch to the soil. Because thermal conductivity of the soil is high relative to that of air, much of the energy absorbed by black plastic can be transferred to the soil by conduction, if contact is good between the plastic mulch and the soil surface. Soil temperatures under black plastic mulch during the daytime are generally 2.8°C higher at a 5 cm depth, and 1.7°C higher at a 10 cm depth, compared to those of bare soil. In contrast, clear plastic mulch absorbs little solar radiation but transmits 85-95%, the extent of transmission depending on the thickness and degree of opacity of the polyethylene.

Light reflectivity may affect not only crop growth but also insect response to the plants grown on the mulch. Examples are yellow, red, and blue mulches, all of which increased green peach aphid populations (Orzolek and Murphy 1993). Mulches with a printed silver surface, or shiny silver coextruded mulches, have been shown to repel certain aphid species and reduce or delay the incidence of aphid-borne viruses in summer squash (Lamont et al. 1990). Research has also been conducted on a photo degradable mulch overlay system, in which the top layer of black photodegradable mulch degrades and increases the exposure of a white non degradable layer (Graham et al. 1995).

We compared two types of cultivation techniques (conventional and plasticulture) in all possible horticultural parameters. The irrigation system was micro drip adapter mediated in our proposed plasticulture technique. We selected twenty plants from both cultivation processes to analysis growth, flowering, fruiting and fruit weight. We only analyzed the initial data related to growth of the plant. We recorded initial growth data and another two sets of data for 15 and 45 days interval. Statistical analysis of data was done to select superior horticulture technique between conventional and plasticulture type strawberry production. While testing with the paired sample test, we compared data sets between conventional and plasticulture method at the same date of growth. In all tests, the mean for plasticulture data set is significantly higher than the conventional data set. The standard deviation is larger in case of conventional data set than the plasticulture data set. Analyzing the mean fruit production, the fruit quality and quantity was better in plasticulture technique. So, from the paired sample test of statistical analysis we can prove that, the growth in case of plasticulture method was superior then of the conventional method. In table-3, we tested the equality of the mean growth for different parameters of plantlet height, number of leaves, north-south and east-west spreading of plant. And we have found all the tests are significant at 2.5% level of significance. So the mean growths are not equal for any of the parameter at different stages. When, we tried to compare the conventional and plasticulture set of data in all possible combination at Least Significant Difference (LSD) test at 5% level of significance, we found all the tests highly significant (Table-4), but some set of data of primary stage was insignificant as we took the sample for both horticulture techniques were homogenous in height, number of leaves and others.

By all statistical mean the data set of plasticulture is better than conventional method. As we switched of the irrigation system of the plasticulture technique, which made the technique much cheaper than the previously practiced plasticulture technique. The plasticulture technique proposed by us was more suitable for the agricultural condition of Bangladesh, as it was higher yield, quality fruit production, lower or zero use of chemical pesticides, low experience is required for maintenance as well as season extending method with a profitable cost benefit ratio.

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Table 1: Paired Samples analysis between conventional and plasticulture procedure in the same stages of growth and fruit production

Number of tests	Criteria of test	Mean	Number of sample (N)	Standard Deviation	Standard Error Mean
Test 1	H15 con.	7.8500	20	1.03999	0.23255
	H15plas.	10.4000	20	0.75394	0.16859
Test 2	H45con.	14.0000	20	0.91766	0.20520
	H45plas.	16.6500	20	0.58714	0.13129
Test 3	L15con.	12.1500	20	2.47673	0.55381
	L15plas.	19.3500	20	1.53125	0.34240
Test 4	L45con.	17.8500	20	2.66112	0.59505
	L45plas.	27.9000	20	1.41049	0.31539
Test 5	N-S 15con.	9.8000	20	1.06869	0.23897
	N-S 15plas.	13.9500	20	0.75915	0.16975
Test 6	N-S 45con.	18.0250	20	1.28222	0.28671
	N-S 45plas.	20.8000	20	0.83351	0.18638
Test 7	E-W15con.	10.0750	20	0.84721	0.18944
	E-W 15plas.	13.0500	20	0.66689	0.14912
Test 8	E-W 45con.	16.2750	20	1.14104	0.25514
	E-W 45plas..	19.6000	20	0.52815	0.11810
Test 9	Fruit con.	6.5500	20	0.60481	0.13524
	Fruit plas.	9.2000	20	.61559	0.13765

Here,
Con. = Conventional plasticulture technique
Plas. = Micro-drip plasticulture technique
H_{int} = Height at the date of planting
H_{15} = Height at the 15 days after the date of planting
H_{45} = Height at the 45 days after the date of planting,
L_{int} =Number of leaves at the date of planting,
L_{15} = Number of leaves 15 days after planting
L_{45} = Number of leaves 45 days after planting
N-$S_{S\ int}$ = North-South spreading of plant at the date of planting
N-$S_{S\ 15}$ = North-South spreading of plant 15 days after the date of planting
N-$S_{S\ 15}$ = North-South spreading of plant 45 days after the date of planting
E-$W_{S\ int}$ = East-west spreading of plant at the date of planting
E-$W_{S\ 15}$ = East-west spreading of plant 15 days after the date of planting
E-$W_{S\ 45}$ = East-west spreading of plant 45 days after the date of planting
FN= Number of fruits

Table 2: Test of significance for the pairs of mean of different parameters of plant by Conventional and plasticulture method.

Tested Differences							T	df	Significance (2-tailed)
					97.5% Confidence Interval of the Difference				
	Criteria for test	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Test 1	H15 con. – H15 plas.	-2.55000	1.23438	.27601	-3.22167	-1.87833	-9.239	19	.000
Test 2	H45 con.- H45 plas.	-2.65000	1.13671	.25418	-3.26852	-2.03148	-10.426	19	.000
Test 3	L15 con. – L15 plas.	-7.20000	2.98417	.66728	-8.82379	-5.57621	-10.790	19	.000
Test 4	L45 con. – L45 plas.	-10.05000	2.79991	.62608	-11.57352	-8.52648	-16.052	19	.000
Test 5	N-S 15con. – N-S 15plas	-4.15000	1.53982	.34431	-4.98787	-3.31213	-12.053	19	.000
Test 6	N-S 45con. – N-S 45plas.	-2.77500	1.39995	.31304	-3.53676	-2.01324	-8.865	19	.000
Test 7	E-W 15con. - E-W 15plas.	-2.97500	.83469	.18664	-3.42918	-2.52082	-15.940	19	.000
Test 8	E-W 45con.– E-W 45plas	-3.32500	1.11538	.24941	-3.93192	-2.71808	-13.332	19	.000
Test 9	Fruit con. – Fruit plas.	-2.65000	1.03999	.23255	-3.21589	-2.08411	-11.395	19	.000

Table 3: Analysis of variance

Parameters	Classes	Sum of Squares	Df	Mean Square	F	Sig.
Height	Between Groups	3173.400	5	634.680	1342.366	0.000
	Within Groups	53.900	114	0.473		
	Total	3227.300	119			
Number of leaves	Between Groups	7269.675	5	1453.935	497.072	0.000
	Within Groups	333.450	114	2.925		
	Total	7603.125	119			
North-South spreading	Between Groups	3865.560	5	773.112	1143.308	0.000
	Within Groups	77.088	114	0.676		
	Total	3942.648	119			
East-West Spreading	Between Groups	2882.317	5	576.463	1069.001	0.000
	Within Groups	61.475	114	0.53		
	Total	2943.792	119			

Table 4: LSD test at 5% level of significance. * means 5% level of significance.

Parameter	Parameters 1	Parameters 2	Mean Difference (Par1-par2)	Standard error	Significance	95% Confidence Interval	
						Lower Bound	Upper Bound
Height	$H_{int\ con}$	$H_{int\ plas.}$	0.00000	0.21744	1.000	-0.4307	0.4307
		$H_{15\ con}$	-4.85000*	0.21744	0.000	-5.2807	-4.4193
		$H_{15\ plas.}$	-7.40000*	.21744	.000	-7.8307	-6.9693
		$H_{45\ con.}$	-11.00000*	.21744	.000	-11.4307	-10.5693
		H45 plas.	-13.65000*	.21744	.000	-14.0807	-13.2193
	$H_{int\ plas}$	H15 con	-4.85000*	.21744	.000	-5.2807	-4.4193
		H15 plas.	-7.40000*	.21744	.000	-7.8307	-6.9693
		H45 con.	-11.00000*	.21744	.000	-11.4307	-10.5693
		H45 plas.	-13.65000*	.21744	.000	-14.0807	-13.2193
	H 15 con	H15 plas.	-2.55000*	.21744	.000	-2.9807	-2.1193
		H45 con.	-6.15000*	.21744	.000	-6.5807	-5.7193
		H45 plas.	-8.80000*	.21744	.000	-9.2307	-8.3693
	H 15 plas	H45 con.	-3.60000*	.21744	.000	-4.0307	-3.1693
		H45 plas.	-6.25000*	.21744	.000	-6.6807	-5.8193
	H 45 con	H45 plas.	-2.65000*	.21744	.000	-3.0807	-2.2193
Number of leaves	Lint con.	Lint plas.	.00000	.54083	1.000	-1.0714	1.0714
		L15 con.	-6.15000*	.54083	.000	-7.2214	-5.0786
		L15 plas.	-13.35000*	.54083	.000	-14.4214	-12.2786
		L45 con.	-11.85000*	.54083	.000	-12.9214	-10.7786
		L45 plas.	-21.90000*	.54083	.000	-22.9714	-20.8286
	Lint plas.	L15 con.	-6.15000*	.54083	.000	-7.2214	-5.0786
		L15 plas.	-13.35000*	.54083	.000	-14.4214	-12.2786
		L45 con.	-11.85000*	.54083	.000	-12.9214	-10.7786
		L45 plas.	-21.90000*	.54083	.000	-22.9714	-20.8286
	L15 con.	L15 plas.	-7.20000*	.54083.	.000	-8.2714	-6.1286
		L45 con.	-5.70000*	.54083	.000	-6.7714	-4.6286
		L45 plas.	-15.75000*	.54083	.000	-16.8214	-14.6786
	L15 plas.	L45 con.	1.50000*	.54083	.006	.4286	2.5714
		L45 plas.	-8.55000*	.54083	.000	-9.6214	-7.4786
	L45 con.	L45 plas.	-10.0500*	.54083	.000	-11.1214	-8.9786
North-south spreading	N-Sint con.	NSintplas.	.00000	.26004	1.000	-.5151	.5151
		NS15 con.	-3.80000*	.26004	.000	-4.3151	-3.2849
		NS15plas.	-7.95000*	.26004	.000	-8.4651	-7.4349
		NS45con.	-12.02500*	.26004	.000	-12.5401	-11.5099
		NS45plas.	-14.80000*	.26004	.000	-15.3151	-14.2849
	N-Sint plas.	NS15 con.	-3.80000*	.26004	.000	-4.3151	-3.2849
		NS15plas.	-7.95000*	.26004	.000	-8.4651	-7.4349
		NS45 con.	-12.02500*	.26004	.000	-12.5401	-11.5099
		NS45plas.	-14.80000*	.26004	.000	-15.3151	-14.2849
	N-S15 con.	NS15plas.	-4.15000*	.26004	.000	-4.6651	-3.6349
		NS45con.	-8.22500*	.26004	.000	-8.7401	-7.7099
		NS45plas.	-11.00000*	.26004	.000	-11.5151	-10.4849
	N-S15 plas.	NS45con.	-4.07500*	.26004	.000	-4.5901	-3.5599
		NS45plas.	-6.85000*	.26004	.000	-7.3651	-6.3349
	N-S45 con.	NS45 plas	-2.77500*	.26004	.000	-3.2901	-2.2599
East-West spreading	E-Wint con.	EWintplas.	.05000	.23222	.830	-.4100	.5100
		EW15con.	-3.67500*	.23222	.000	-4.1350	-3.2150
		EW15plas.	-6.65000*	.23222	.000	-7.1100	-6.1900
		EW45con.	-9.87500*	.23222	.000	-10.3350	-9.4150
		EW45plas.	-13.20000*	.23222	.000	-13.6600	-12.7400
	E-Wint plas	EW15con.	-3.72500*	.23222	.000	-4.1850	-3.2650
		EW15plas.	-6.70000*	.23222	.000	-7.1600	-6.2400
		EW45con.	-9.92500*	.23222	.000	-10.3850	-9.4650
		EW45plas.	-13.25000*	.23222	.000	-13.7100	-12.7900
	E-W15 con.	EW15plas.	-2.97500*	.23222	.000	-3.4350	-2.5150
		EW45con.	-6.20000*	.23222	.000	-6.6600	-5.7400
		EW45plas.	-9.52500*	.23222	.000	-9.9850	-9.0650
	E-W15 plas.	W45 con.	-3.22500*	.23222	.000	-3.6850	-2.7650
		EW45plas.	-6.55000*	.23222	.000	-7.0100	-6.0900
	E-W45 con.	EW45plas.	-3.32500*	.23222	.000	-3.7850	-2.8650

Figure 1: Preparation of bed for both Conventional and Plasticulture method by following same protocols.

Figure 2:. Soil solarization for pathogen free soil.

Figure 3: Plasticulture bed preparation

Figure 4: Micro Drip Adapter Mediated Irrigation in plasticulture system.