NURSERY STUDIES IN COCOA

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Introduction

Cocoa is a crop of humid tropics and is being cultivated under coconut and arecanut gardens and in partially cleared forests, making it conducive for pathogens and weeds. According to the World Cocoa Foundation the area under cocoa is around 7 million ha and about three million tons of cocoa is produced annually. In India, area under cocoa is spread over Kerala, Karnataka, Andhra Pradesh and Tamil Nadu with 46,318 Ha and the total production is 12,954 MT. Andhra Pradesh ranks first with an area of 16,969 ha whereas Karnataka ranks first in production with 7,250 MT and the productivity is the highest in Kerala with 592 kg per ha. The average productivity of Indian cocoa is 380 kg per ha. The demand of chocolate industry and confectionaries is portrayed as 60,000 MT for the year 2025 for which around 150.7 million seedlings required to bring 2,20,000 ha under cocoa cultivation. The foremost necessity to get sustainable and profitable yield is the supply of quality planting materials (Peter *et al.,* 2002). The production and management of planting materials in the nursery decides the performance of cocoa in the field and ultimately the quality of products which necessitated the nursery studies.

1. Soil solarization studies

Soil solarization is a method of heating soil through sunlight and by covering it with polythene sheets to control weeds, soil borne diseases and to produce healthy seedlings. It is called as hydrothermal disinfection and consider as a non-chemical alternative. Solarization of nursery beds, potting mixtures and main fields were found to be effective and in cocoa, black polythene mulches were used in plantations of Ghana, Malaysia and Ivory Coast.

This experiment was conducted at CPCRI, Regional Station, Vittal, Karnataka to study the effect of soil solarization on germination, growth and health of cocoa seedlings. The regular potting mixture standardized for cocoa was prepared as fine tilth without any pebbles or debris in the ratio 2:1:1 (Soil: FYM: Sand). The initial temperature of potting mixture was measured and it was 33.5^{0}C. The mixture was spread in the leveled open ground to a height of 15 cm and moistened with water to increase the thermal sensitivity of resting structures of soil- borne plant pathogens, weeds and to improve heat conduction. 50 kg each of this potting mixture was covered with 150-200 gauge black, white, transparent and green polythene sheets tightly and closely to the ground. Edges of the sheet were sealed with soil to keep it in position in order to maintain the temperature and moisture inside the sheets. As poly green house had raised temperature than outside environment one set of potting mixture was kept inside and the initial temperature measured was 35^{0}C. Summer season is considered as best for solarization and this trial was started during April, continued for 40 days and sowing was taken up in May. Temperatures of the covered mixtures gone upto 40 to 45^{0}C after solarization.

After 40 days of solarization, polythene sheets were removed and 50 seeds of the clone NC-45/53 scarified with sand were sown. Initial germination was noted after 10 days and percentage of germination was accounted after 15 days. Growth measurements were taken in 25 numbers of 4 month old seedlings under each treatment and subjected to ANOVA. Cocoa nursery at Vittal is in operation throughout the year (Elain Apshara *et al.,* 2007) and so one more trial was conducted during the post monsoon season in the month of October to study the effectiveness of solarization. Compared to summer the rise in temperatures was lesser during this season (Table 1). Early germinations were noticed in transparent cover and poly green house conditions during both the seasons. It might be because of their effectiveness in heating and better transmittance of light than other thicker sheets. During May, the highest (98%) percentage was recorded in the treatment with transparent cover followed by black polythene sheet

(96%) and next best germinations were observed in open and poly green house conditions (Table 1). Fluctuations in day and night temperature is said to be lesser in transparent sheets and temperature increases in a range of 3-4^{0}C and in black sheet it raised to 2-3^{0}C compared to other sheets (Palanikumar, 2007) and that might be the reason for effective solarization. Though reasonably good germination was observed in poly green house condition more of bend seedlings were observed during later stage of growth. Increase in temperature and heat transmission inside the green house might be the reason for that.

During October, the germination percentages were slightly lesser than summer. The highest germination (94%) was observed in black sheet followed by transparent sheet and open condition (92%). However, more of weed growth was observed in transparent sheet during both seasons. It might be because of the fact that clear sheets absorbs more solar light but blocks outgoing radiation, which was evident from the water droplets seen inside these covers, ultimately provided favorable environment for weeds (Maruthi Prasad *et al.,* 2009). During the following monsoon season in June, the rains aggravated the weed growth as well as die-back in seedlings in four treatments except green and black coverings. The maximum die-back was observed in open condition during May (8.5%) and October (6.5%). During post monsoon season also die-back was lesser in green and black sheets (Table 1). This was in corroboration with the results of Katan (1981) on solarization in different crops and its effectiveness in control of pathogens in gladiolus (Raj and Upmanyu, 2006) and mango wilt in nurseries (Raj and Gupta, 1996).

Table 1. Potting mixture temperatures, germination and disease incidence in cocoa seedlings

Condition	Potting mixture temperatures before and after solarization (^{0}C)				Germination %		Die-back %	
	May		October					
	Pre	Post	Pre	Post	May	October	May	October
Open sun	33.5	38.0	32.0	35.0	94	92	8.5	6.5
Poly green house	35.0	45.0	35.0	38.0	94	90	6.4	4.4
White	33.5	36.0	32.0	35.0	92	88	6.5	4.5
Transparent	33.5	38.0	32.0	35.0	98	92	6.1	6.5
Green	33.5	38.0	32.0	36.0	92	90	4.3	2.2
Black	33.5	40.0	32.0	37.0	96	94	4.2	2.1

Growth observations were taken in seedlings of all treatments which showed significant differences (Table 2). Summer solarized seedlings showed very good growth during fourth month with respect to height, girth, number of leaves, length and breadth of leaves. Among the treatments, seedlings solarized in black polythene showed good growth with respect to height (35.5 cm) and girth (2.5 cm). More number of leaf production was noticed in black (15.6) and green (15.0) sheets. Though leaf length and breadth recorded non-significant results among treatments, it was highest in open and black and green covers. This type of higher growth and yield in different crops including nursery of fruits and vegetables was reported by earlier workers (Patel, 2001 and Raj, 2004). Black and transparent poly mulches increased the soil nutrient level and ultimately increased the growth and yield of strawberry (Gupta and Acharya, 1994) and in Chausa and Langra varieties of mango (Singh *et al.,* 2009). Black polythene mulch has increased 25 per cent seedling growth in cocoa also (Frimbong *et al.,* 2003).

The growth values recorded during post monsoon season were lesser than summer season. Height, girth and leaf numbers were maximum in green, black and open conditions. Length and breadth showed non-

significant results but maximum in green and black sheets (Table 2). Ashwani Kumar and Gulshan (2008) recorded the benefits of plastic sheets of different colors in conserving moisture, warming soil, controlling weeds and pathogens, increasing the phosphorus and potassium availability. Color sheets and mulches especially green mimics the reflective patterns of the green leaves of neighboring plants, tricks the plant to put more energy into shoots to outgrow other plants which was happened here also during post monsoon season.

Table 2. Growth observations of cocoa seedlings

Condition	Height (cm)		Girth (cm)		Leaf No.		Leaf length(cm)		Leaf breadth(cm)	
	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
Open sun	34.2	31.8	2.39	2.32	14.7	14.2	19.5	18.6	6.61	6.34
Poly house	31.5	31.6	2.27	2.24	14.5	13.0	18.6	17.7	6.37	5.81
White sheet	30.3	30.1	2.35	2.21	12.1	11.8	19.2	18.5	6.70	5.91
Transparent	31.3	30.5	2.20	2.10	12.7	12.2	18.3	18.1	6.66	6.06
Green	32.6	33.9	2.43	2.38	15.0	14.7	19.2	18.8	6.79	6.48
Black	35.5	32.3	2.51	2.34	15.6	14.4	19.3	19.0	6.90	6.64
SEd	1.17	1.38	0.07	0.07	0.73	0.75	0.90	0.52	0.33	0.47
CD (5%)	2.32	2.85	0.13	0.14	1.44	1.55	NS	NS	NS	NS

It was concluded that, soil solarization with black polythene covers was effective in cocoa germination, growth of seedlings and reduced weed growth and die-back during summer season whereas, during post monsoon season green covers were preferable.

2. Potting mixture studies

In the recent years, organic cultivation gained importance and use of different types of composts and microbial cultures are being practiced in plant production. As a measure to utilize the farm wastes and by-products in the areca-cocoa intercropping system, several potting mixtures were tried. In Ghana, a shortage of top soil led to studies of alternative media and various mixtures of soil with sand and waste cocoa shell were tested. Considerable variability in plant height, stem girth, leaf area, dry shoot weights due to soil amendments with cocoa pod husk was observed in Nigeria (Orisajo *et al.,* 2005). In Brazil, bean shells of *Theobroma grandiflora* is widely used along with forest soil. In West Africa, top soil alone is used for filling the bags after sieving. Ahenkorah (1969) and Wessel (1967) indicated the superiority of organic soil amendments to inorganics in nursing cocoa seedlings. A medium consisting of 25% of coconut husk and 75% of sand by volume was found to be best in terms of seedling growth (Erwiyono and Goenadi, 1990). There has been a growing interest in the use of cocoa pod husk for industrial and commercial purposes in cocoa producing countries as cited by Ahenkora *et al.,* 1973, 1981 and 1987. Ofori-Frimpong *et al.,* 2006 suggested that cocoa pod husk based compost and suitable top soil in a mixture of 1:2 or 1:3 could be used as potting medium for nursing cocoa seedlings. Vermiproducts as a nursery mixture had a significant effect on growth parameters of Caroba (*Jacaranda micrantha Chamisso.*) seedlings (Tedesco *et al.,* 1999) and in *Simarouba glauca, Pongamia pinnata* and *Delonix regia* (Gopi, 2002). Srinivasa Reddy *et al.,* 2001 and Borah *et al.,* 2008 seen vigorous growth of coconut and arecanut seedlings with sand and vermicompost as potting mixtures. With this background the following study was taken up.

The standard potting mixture composition comprising of 2:1:1 (Soil: Sand: FYM) was used as 1 treatment and replacing FYM with coir compost, vermicompost, cocoa husk, cocoa shell and areca husk in other treatments keeping top soil alone as control was tried. 50 seeds of clone I-14 were sown and germination

percentages were recorded in all treatments during 7, 10 and 15 days after sowing. Early germination and high percentage of germination was noticed in treatment with soil alone and mixture with farm yard manure (Table 3). Growth of the seedlings showed considerable difference after 2 months of germination with respect to girth, number of leaves and leaf breadth. Seedlings grown to maximum height in mixtures with vermicompost and farm yard manure and they were high in girth also. The potting mixtures with vermicompost and coir compost showed more leaf numbers and size (Table 4).

Table 3. Effect of potting mixtures with Soil: Sand: FYM (2:1:1) on cocoa germination

S.No.	Potting Mixture	Germinination (%)			Germination (%)
		7 days after sowing	10 days after sowing	15 days after sowing	
1	Soil alone	35	40	40	77
2	FYM	36	41	41	78
3	Coir compost	19	36	36	61
4	Vermicompost	15	37	37	59
5	Cocoa pod husk	20	32	34	56
6	Cocoa bean shell	18	33	34	57
7	Areca husk	16	33	33	55

Table 4. Effect of potting mixtures with Soil: Sand: FYM (2:1:1) on cocoa seedlings

Mixtures	Height (cm)	Girth (cm)	No. of leaves	Leaf length(cm)	Leaf breadth(cm)
Soil alone	23.88	1.55	8.27	15.55	5.77
FYM	25.47	1.93	12.87	16.27	6.22
Coir compost	24.13	1.85	10.87	16.82	6.85
Vermicompost	27.33	2.03	12.27	17.16	6.32
Cocoa pod husk	24.42	1.75	12.03	16.65	5.74
Cocoa bean shell	24.07	1.86	11.33	15.61	5.37
Areca husk	24.11	1.77	9.33	15.42	5.69
CV%	13.83	12.36	17.78	13.36	18.13
SEd	1.25	0.08	0.71	0.79	0.40
CD (5%)	NS	0.16	1.41	NS	0.79

To study the effect of organic components and to confirm the previous results one more trial in the proportion of 1:1:2 was tried increasing the proportion of organic amendments. High germination percentages were observed, which ranged from 63% in cocoa shell to 92% in soil alone followed by FYM, cocoa husk and areca husk (Table 5). Seedlings showed significant results with all growth parameters (Table 6). Height and girth were maximum with FYM and vermicompost. Production of leaves and size of leaves were highest in vermicompost and FYM. Both are comparable with each other and vermicompost is an alternate source for farm yard manure in production of cocoa seedlings and it encourages on-farm composting.

Table 5. Effect of potting mixtures with Soil: Sand: FYM (1:1:2) on cocoa germination

S.No.	Potting Mixture	7 days after sowing	10 days after sowing	15 days after sowing	Germination %
1	Soil alone	46	46	46	92
2	FYM	43	43	43	86
3	Coir compost	39	38	38	77
4	Vermicompost	35	35	35	72
5	Cocoa husk	42	40	40	81
6	Cocoa bean shell	20	30	44	63
7	Areca husk	40	40	40	80

Table 6. Effect of potting mixtures with Soil: Sand: FYM (1:1:2) on cocoa seedlings

Mixtures	Height (cm)	Girth (cm)	No. of leaves	Leaf length(cm)	Leaf breadth(cm)
Top Soil	17.33	1.53	8.47	9.45	4.41
FYM	19.66	1.69	9.13	10.30	4.75
Coir compost	17.48	1.53	7.27	8.72	4.38
Vermicompost	18.63	1.61	9.27	11.88	4.96
Cocoa husk	17.20	1.55	6.73	9.87	4.33
Cocoa shell	17.77	1.56	8.27	10.23	4.39
Areca husk	16.43	1.50	7.80	9.05	4.13
CV%	12.94	8.72	17.90	16.33	14.97
SEd	0.84	0.05	0.53	0.59	0.24
CD (5%)	1.67	0.10	1.05	1.18	0.49

3. Biopriming studies

Bio-priming refers to the application of plant growth promoting microbes to the plant or potting mixture to enhance seedling growth and health. Different microbial cultures isolated from cocoa gardens of various locations were tested at CPCRI, Kasaragod for their efficiency. Among the Fluorescent pseudomonads, *Pseudomonas putida* biovar A. KDSF 23 and *Pseudomonas* sp. KDSF 7 were identified as suitable for cocoa, which were isolated from cocoa gardens of CPCRI, Research Centre, Kidu, Karnataka. The effect of these particular cultures was tested in cocoa seedling growth at CPCRI, Regional Station, Vittal. Cocoa seeds were sown in polybags with 2:1:1 (Soil: Sand: FYM) potting mixture. After completion of soldier phase of germination *i.e.* 1 month after sowing 20 g of culture powder was applied in the poly bags. Growth observations were taken 1 month after application and continued upto 4 months in 50 seedlings each and the results are given below.

During first month of growth, girth showed significant difference between treatments and in the second month no. of leaves, leaf length and breadth recorded significant differences and girth of seedlings and the leaf size were more than the control (Table 7). At 3 months all characters showed values more than the control. At the age of 4 months, which is a suitable stage for planting, height of seedlings and number of leaves showed significant difference with bio-primed seedlings (Table 8). Throughout the growth period bio-primed seedlings showed considerable difference and increased growth than the mixture without microbial culture. KDSF-7 and KDSF-23 were comparable to each other.

Table 7. Effect of microbial cultures on cocoa seedling growth in early months

Characters	1 month after application					2 months after application				
	C	KDSF-7	KDSF-23	SEd	CD	C	KDSF-7	KDSF-23	SEd	CD
Height (cm)	32.7	31.5	31.9	-	-	39.1	38.7	39.5	-	-
Girth (cm)	3.74	4.12	3.94	0.09	0.18	4.70	4.87	4.76	-	-
No. of leaves	6.94	7.0	6.7	-	-	10.1	9.06	9.7	0.40	0.79
Leaf length (cm)	13.7	12.2	12.8	-	-	14.9	16.6	16.7	0.59	1.15
Leaf breadth (cm)	4.26	4.57	4.57	-	-	4.75	5.66	5.54	0.19	0.38

Table 8. Effect of microbial cultures on cocoa seedling growth in later months

Characters	3 months after application					4 months after application				
	C	KDSF-7	KDSF-23	SEd	CD	C	KD-7	KD-23	SEd	CD
Height (cm)	46.5	47.2	48.9	-	-	51.5	53.8	56.3	1.58	3.09
Girth (cm)	5.7	5.92	5.73	-	-	6.62	6.71	6.67	-	-
No. of leaves	13.1	12.6	13.6	-	-	13.7	12.7	14.0	0.52	1.02
Leaf length (cm)	18.3	20.1	19.6	-	-	19.4	20.4	20.8	-	-
Leaf breadth (cm)	5.69	6.36	6.03	0.24	0.47	6.08	6.25	6.22	-	-

4. Bean studies

For commercial seedling production, seed pod requirement is very high which should be of correct size, maturity and health. Sorting, selecting suitable seeds, seed treatment etc. also played a major role in production of quality seedlings (Elain Apshara, 2010). Seeds for sowing should be bold, large, from middle of the pod, weighing around 3 g when wet and 1 to >1 g when dry. Seeds in cocoa are recalcitrant without dormancy period and so beans once extracted from pods should be sown immediately before losing viability. Seeds start germination in about a week and will continue for another one week. Healthy seeds from well matured pods usually give a germination of 90 to 95 per cent. Adenikinju (1977) observed that rate of germination of cocoa beans vary with maturity status, bean size and other inherent and external factors. Cocoa seeds will germinate at any time of the year with adequate irrigation. Apart from the above said selection criteria, nurseries tend to use multiple types of seeds obtained from the bulk harvest. This study was taken up to assess whether the condition of seed pod or seeds affect the germination considerably under Karnataka condition. The treatments included 3 maturity status such as mature green, ripe and over ripe seed pods and 6 bean conditions, *viz.,* seeds sown as such without any seed treatment, seeds sown after removing mucilage, seeds without peel, seeds without 1 cotyledon before sowing, removal of 1 cotyledon after germination and removal of 2 cotyledons after germination. 50 seedlings of the clone NC 45/53 in each treatment was observed for germination percentage. Well matured green pod showed 94% germination. Beans without mucilage and 1 cotyledon recorded high germination (Table 9), survival and good growth.

Table 9. Effect of bean types on germination

S.No.	Bean condition	Germination %
1	Seeds as such	92
2	Without mucilage	96
3	Removed peel (testa)	90
4	Removed 1 cotyledon	94
5	Removed 1 cotyledon after germination	90
6	Removed 2 cotyledons after germination	90
7	Mature green pod	94
8	Ripe pod	92
9	Over ripe pod	86

Conclusion

It is concluded that solarization of potting mixtures with black polythene covers during summer was effective in enhancing germination, growth of seedlings and reducing weed growth and die-back. Green covers were preferable during post monsoon season. Early and high percentage of germination was observed with farm yard manure. Healthy seedlings were observed in the potting mixtures with vermicompost and coir compost and they can be used as an alternate source for farm yard manure. Bio priming of potting mixtures with *Pseudomonas* cultures KDSF 7 and KDSF 23 showed significant growth and health improvement. Germination studies for the possibility of utilizing different category of seeds revealed that higher percentage of germination was observed in seeds without mucilage, testa and even without one cotyledon.

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