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Investigation on the Effects of Planting Time and Plant Geometry on the Activity of Sucking Pests of Chilli *Capsicum Annuum L*

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Abstract- Field experiments were conducted at the Main Agricultural Research Station, UAS, Dharwad, Karnataka, India to investigate the effect of planting time and plant geometry on the activity of chilli sucking pests. Pooled data from two years revealed that, the interaction effect between the date of planting and different spacings was significant. Significantly lower level of sucking pest and leaf curl index was observed in the interaction of July 15th planting and 90x60cm spacing followed by July 15th and 60x60cm and July 15th and 75x45cm treatments. Whereas, it was higher in interaction of June 30th and 60x30cm. Similar pattern of treatment significance was observed in case of natural enemy population also. Significantly highest chilli yield was registered in interaction of July 15th planting and 90x60cm spacing (4.21 q/ha) whereas, lowest chilli yield of 1.99 q/ha was registered in the combination of June30th + 60x30cm treatment. The interaction effect between July 15th and 90x60cm was found to be the most cost effective which recorded highest net returns (Rs 15,921/- per ha).

Keywords: *leaf curl index, natural enemy, plant geometry, planting time, sucking pests.*

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Investigation on the Effects of Planting Time and Plant Geometry on the Activity of Sucking Pests of Chilli *Capsicum Annuum L*

Y. H. Sujay [α] & R. S. Giraddi [σ]

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I. Introduction

Chilli (*Capsicum annuum L.*) is a tropical and subtropical crop grown all over India. It is an important versatile spice as well as vegetable crop. India is the largest producer and consumer of chilli in the world. Chillies constitute about 20 per cent of Indian spice exports in quantity and about 14 per cent in value. It's grown in almost all the state throughout the country. Andhra Pradesh is the largest producer of chilli in India and contributes about 30% to the total area, followed by Karnataka (20%), Maharashtra (15%), Orissa (9%), Tamil Nadu (8%) while other states contributing nearly 18% to the total area under chilli. Among the plethora of constraints in chilli cultivation, the attack by a multitude of insect pests and mite at different crop stages is of utmost concern. The pest spectrum of chilli crop is complex with more than 293 insects and mite species debilitating the crop in field as well as in storage (Anon., 1987 and Dey et al., 2001). A total of 39 and 57 species of pests were recorded by Reddy and Puttaswamy (1983 and 1984) in nursery and field crops, respectively in Karnataka. One of the practical means of increasing chilli production is to minimize losses caused by major sucking pests, the most important among them are green peach aphid (Myzys persicae Sulzer, Aphis gossypi Glover), thrips (Scirtothrips dorsalis Hood) and yellow mite (Polyphagotarsonemus latus Banks) (Berke and Sheih, 2000). In Karnataka thrips, mites, aphids and whiteflies have been identified as sucking pests of chilli of which chilli leaf curl caused by mite and thrips are serious (Puttarudriah, 1959). Besides, a number of viruses are transmitted by aphids, whiteflies etc which result into a complex murda (Gundannavar et al., 2007). The yield losses due to these pests are estimated to be 50 per cent (Ahmed et al., 1987; Kandasamy et al., 1990 and Hosmani, 2007). The loss caused by the thrips is reported to range from 50 to 90 per cent (Borah, 1987) and fruit borers is to an extent of 90 per cent (Reddy and Reddy, 1999).

Pesticide residues in chilli are of great concern from the point of domestic consumption and exports as well. Residues in chilli have been reported by various workers in India (Awasthi et al., 2001; Dhotre et al., 2001 and Joia et al., 2001; Singh et al., 2006; Reddy et al., 2007; Rao et al., 2009; Suganthy et al.,2010 and Jyoti et al., 2012). David (1986) identified that application of commonly used insecticide aimed in checking sucking insects like thrips and aphids caused resurgence of P. latus on chilli.

Though, insecticidal interventions bring down the pest population, they have led to the problem of residues in fruits. The presence of pesticide residues has seriously affected the export of chillies. It is learnt that Byadagi chilli lots were rejected at international ports of importing countries very often due to high pesticide residues. The reported presence of residues of many insecticides including ethion, chlorpyriphos, cypermethrin, endosulfan and quinalphos have seriously affected the export of chillies (Anon., 2003) Besides, indiscriminate use of chemicals has led to the many undesirable problems like resurgence, destruction of natural enemies, environmental pollution etc.

Due to the luxuriant plant canopy and succulency, crops receive maximum pest damage. In this backdrop, crop intensification, crop nourishment etc

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may create favourable (and at times unfavourable) situations for the pests through physical factors (For example, chilli viruses which are transmitted by insects are also known to be carried through plant sap) or biological factors (Gundannavar et al., 2009). So, different strategies have to be involved for keeping the pest in check and stabilizing the productivity of cropping system. Date of planting and spacing is one of the crop habitat diversifications that are to be looked into, which have the potential to become viable components of a sound IPM programme.

II. Material and Methods

The field experiments were carried out for two seasons to know the effect of planting time and plant geometry on the activity of sucking pests of chilli during Kharif 2008-09 and 2009-10. The experiment was carried out at the MARS, UAS, Dharwad. The experiment was laid out in a split plot design with three replications across four dates of planting viz., M1- June 30th, M2- July 15th, M3- July 30th and M4- August 15th as main plot treatments and four spacings viz., S1- 90 x 60cm, S2- 60 x 60cm, S3- 75 x 45cm and S4- 60 x 30cm as sub-plot treatments. The seeds were sown on the raised seed bed on May 15th, May 30th, June 15th and June 30th in 2008-09 and 2009-10. Forty-five days old seedlings were transplanted as per the dates with fifteen days interval in plots size of 5.4 X 4.8 m with different spacings. All management practices were followed as per recommended package of practices except the plant protection measures against target pests.

a) Observations

The population count of aphids and thrips were taken at 30, 60 and 90 days after transplanting (DAT). While the population count of mite was taken at 60 and 90 DAT. For counting the population, five plants were selected randomly in each plot and tagged. Six leaves on the top canopy of each selected plant were observed by using binocular microscope in laboratory following destructive sampling procedure. Ten plants were selected randomly in each plot and scored for leaf curling index (LCI) at 70 and 100 DAT visually following the 0-4 scale (Niles, 1980) and subjected for statistical analysis. Pooled analysis for both the years was done with the help of M StatC statistical software.

Population count of both grubs and adults of natural enemy fauna that included coccinellid beetles, Menochilus sexmaculatus F and chrysopids, Chrysoperla zastrow sillemi (Esben-Peterson) were recorded in each treatment by following the standard procedure. Population count was taken on five randomly selected plants at 60 and 90 DAT. The population density of predatory coccinellids beetles and chrysopids was recorded as number of coccinellids/plant and chrysopids/plant, respectively. Pooled analysis for both the years was done with the help of M StatC statistical software. Green chillies were harvested from five randomly selected plants in each plot as well as from entire plot separately and yield per plant and per plot was recorded during each picking. Total yield was calculated by adding the yield of each picking. Totally four pickings were done and average of four pickings were given. The per plot yield was converted to quintals per hectare. Dry chilli yield was obtained from the green chilli yield as per the procedure given by Anon. (2004), with the ratio of conversion of green chilli to dry chilli being 10:1. Cost effectiveness of each treatment was assessed based on net returns. Net returns of each treatment were worked out by deducting total cost of each treatment from gross returns. Total cost of production included both cultivation as well as plant protection charges. The B: C ratio was worked out by dividing the gross return with the total cost of cultivation. The data on mean population of sucking pests and natural enemies were transformed to Ö x+0.5 and then subjected to one way ANOVA using M-STATC ® software package. The treatment effect was compared by following Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

III. Results and Discussion

Pooled data from two years on the effect of planting time and plant geometry on the activity of sucking pests, in general indicated the effectiveness of planting time, plant spacing and interaction of both in suppressing the pests activity vis-à-vis comparison treatments. The details are presented here under.

a) Aphids

Pooled data from two years revealed that at 30 DAT, among the main plots, M2 recorded significantly lower aphid population (0.26/leaf) followed by M3 and M4 which recorded aphid population of 0.30 and 0.40 per leaf respectively. While M1 recorded higher aphid population of 0.54 per leaf (Table 1). Among different spacings (subplots) significantly least population of aphids was recorded in S1 (0.29/leaf) followed by S2 (0.34/leaf). While, S4 registered higher aphid population of 0.49 per leaf. The interaction effect between the plating dates and different spacings was found to be significant. Significantly lower aphid population was recorded in M2 + S1 (0.21/leaf) followed by M2 + S2 (0.25/leaf). Whereas, higher aphid population was registered in June 30 and 60X30cm combination i.e. M1 + S4 (0.74/leaf).

At 60 DAT, the main plot treatment M2 registered significantly lower aphid population of 0.22 per leaf and was found to be statistically on par with the M3 (0.26/leaf). Whereas, significantly higher aphid population per leaf was registered in M1 (0.50/leaf) followed by M4 (0.35/leaf). Among subplots S1 (90X60cm) registered significantly lower aphid population (0.25/leaf) followed by S2 (0.30/leaf). While

S4 recorded higher aphid population of 0.50 per leaf. The interaction effect between planting date and spacing did not have any significant effect on aphid population. At 90 DAT, the pooled aphid population showed similar pattern of treatment differences as evidenced during 30 DAT in main plot and subplot treatments. The interaction effect also followed similar trend (Table 1).

b) Thrips

At 30 DAT, among the main plots, M2 registered significantly least thrips population (0.16/leaf) followed by M3 and M1 which recorded thrips population of 0.32 and 0.47 per leaf respectively. While M4 recorded higher thrips population of 0.60 per leaf (Table 2). Among the different spacing i.e., in subplots, significantly less population of thrips was observed in S4 (0.24/leaf) followed by S1 (0.28). Whereas S3 subplot registered higher thrips population of 0.39 per leaf. The interaction effect between the planting date and different spacings was found to be significant. The interaction treatment M2 + S1 recorded significantly lower thrips population (0.08/leaf) followed by M2 + S2 (0.14) whereas higher thrips population was observed in M4 + S4 (0.72/leaf). At 60 DAT, the pooled thrips population showed similar pattern of treatment differences as evidenced during 30 DAT in main plot and subplot treatments. The interaction effect also followed similar trend. The thrips population ranged from 0.18 to 0.53 and 0.33 to 0.44 per leaf during 90 DAT in the main plot and subplot treatments respectively. Significantly lower thrips population of 0.18 and 0.33 per leaf was registered in M2 of main plot and S1 of sub plot treatments, respectively. While M1 (0.53/leaf) and S3 (0.44) registered higher thrips population in main plot and subplot treatments, respectively. However, the interaction effect between main plots and subplots did not have any significant role in thrips population (Table 2).

c) Mites

At 60 DAT, among the main plot treatments, significantly lower mite population per leaf was registered in M2 (0.36/leaf) and was found to be statistically at par with the M3 (0.44/leaf). Whereas, significantly higher mite population per leaf was recorded in M2 (0.71) followed by M4 (0.56).

Among the subplots, S1 registered significantly lower mite population of 0.44 per leaf. While, moderate number of mites was registered in S2 and S3. Significantly higher mite population was recorded in S4 with a population of 0.65 mites per leaf. The interaction between planting data and different spacings did not have any significant effect on mite population. At 90 DAT, among the main plot treatments and sub plot treatments the mite population ranged from 0.33 to 0.56 and 0.28 to 0.50 mites per leaf, respectively. However, the difference in the population was not statistically significant in both mail plot treatments and subplot treatments. The interaction effect was also non-significant (Table 3).

d) Leaf curl index

With respect to pooled data of leaf curl index, among the main plot and subplot treatments, significantly least leaf curl index was recorded in July 15th of main plot (0.30 and 0.29) and 90 X 60cm of subplot (0.44 and 0.47) treatments at 70 and 100 DAT respectively. While June 30th planting (0.85 and 0.91) and 60 X 30cm spacing (0.62 and 0.67) registered significantly higher leaf curl index in main plot and subplot treatments, respectively. Interaction effect between main plot and sub plots was found significant. Significantly least leaf curl index was registered in the combination of July 15th transplanting at 90 X 60cm spacing (0.25 and 0.26) followed by July 15th + 75 X 45cm (0.26 and 0.31) and July 15th + 60 X 60cm (0.31 and 0.27) whereas significantly higher leaf curl index was registered in June 30th + 60 X 30cm (0.94 and 1.06) at 70 and 100 DAT (Table 3).

There is no much information in literature to suggest the effect of date of planting and spacing on the activity of sucking pests except very few reports. The weather parameters like precipitation, sunlight, relative humidity have been reported to be optimum for transplanting of Byadagi chilli during July in the region (Anon., 2004), leading to better rooting and establishment. June planting which is quite unusual in the tract, perhaps predisposes the crop to early infestation by sucking pests due to non-availability of host. While late planting, as it is known in many crops, attracts greater intensity of pests and subsequent plant damage. The present investigations are in close agreement with Kempegowda (1980) who reported that 15th July transplanting of all the three-chilli varieties viz., NP-46A, Jwala and C-1 recorded the highest yields of green pods than late planting. Late planted crop was liable for heavy infestation by insect pests and mites. Time of transplanting of chilli influences the incidence of pests and diseases. Chilli crop transplanted in early June and July escapes incidence of thrips and mites than the crop transplanted in late July and early August as evidenced by Hosmani (1982). Similarly, Mallapur et al. (1987) found lower incidence of leaf curl due to thrips and mites when crop planted until July. Patel (1992) reported that the population of chilli thrips remain low during July- August due to rains and showed a peak in September- October. Low incidence of leaf curl was observed in chilli crop, in Maharashtra planted until 15th July, while late-planted crop (15th August and 30th August) was severally attacked by leaf curl. Planting of chilli from 30th June to 15th July could escape the thrips damage as reported by Bagle (1998). All these earlier reports corroborate with the results obtained in present study.

The present experimental results are also in line with the study of Gayathri Devi and Giraddi (2007) who

repored that chilli planted before 15th July receives significantly less chilli leaf curl incidence. Nagaraja et al. (2008) evidenced that sowing the crop during June I and II fortnight as well as July I fortnights emerged as better and optimum dates for Byadagi chilli under irrigated conditions. Significantly lower mean population of thrips and mites were registered in protected and unprotected conditions, respectively. This phenomenon of effect of planting date and plant geometry is also seen in other crops. Thiara and Kang (2006) studied the effect of date of sowing of plants for managing the groundnut bud necrosis disease. Percent disease incidence and severity were highest in case of May end sown crop, which was followed by early May and early June sown crop. However, the incidence and severity were significantly low in June end sown crop.

e) Natural enemies

The pooled data on the activity of natural enemies suggested that they were found greatly distributed in main plot and sub plots having different planting time and spacings (Table 4). Among the main plots, M2 i.e. July 15th transplanted crop (1.34, 1.38 coccinellids/plant and 1.62, 1.63 chrysopids/plant) recorded significantly more number of predators and was found to be statistically at par with July 30th (1.29, 1.32 coccinellids/plant and 1.39, 1.43 chrysopids/plant) followed by August 30th (1.17, 1.20 coccinellids/plant and 1.29, 1.33 chrysopids/plant) whereas June 30th (1.10, 1.14 coccinellids/plant and 1.17, 1.26 chrysopids/ plant) transplanted crop registered significantly less mean predators count at 60 and 90DAT respectively. Among the different spacings, significantly higher predator count was recorded in 60 X 30cm spacing (1.39, 1.42 coccinellids/plant and 1.54, 1.55 chrysopids/ plant) and was found to be statistically at par with 60 X 60cm followed by 75 X 45cm. While 90 X 60cm transplanted crop (1.07, 1.11 coccinellids/plant and 1.19, 1.29 chrysopids/plant) registered lowest predator population count per plant. The interaction between main plots and subplots was significant. The interaction of July 15th transplanted crop at 60 X 30cm spacing (1.50, 1.52 coccinellids/plant and 1.71, 1.71 chrysopids/ plant) recorded significantly more number of predators followed by July 30th + 60 X 30cm and August 15th + 60 X 30cm. Whereas, significantly least number of predator count was observed by the interaction of June 30th transplanted crop at 90 X 60cm spacing (0.95, 0.98 coccinellids/plant and 1.02, 1.21 chrysopids/plant) (Table 4).

There is no much literature available on the effect of sowing date and plant spacing on the activity of predators in chilli crop. However, in other crops, Singh and Nath (2007) indicated that effect of dates of sowing of Brassica juncea on coccinellid beetle of Lipaphis erysimi kalt. Maximum coccinellid population were observed in the last week of February (when crop was on its maturity), while minimum in the last week of December. Bana et al. (2012) studied the seasonal incidence of major pests of cabbage and their natural enemies. The coccinellid beetle was recorded as a important predator of aphid, which was maximum in the second and third week of January. Similarly, Siddiqui et al. (2009) carried out an experiment to determine the influence of planting dates on aphid and their natural enemies in cauliflower varieties. Aphid population was significantly lower in early planting of cauliflower (late September) and higher in case of late planting of cauliflower trial (late October). The rate of parasitism and predation on early planting trial were 3.86 per cent and 0.82 per cent. In late planting trial, the rate of parasitism and predation were 3.3 per cent and 0.42 per cent. Meena and Kanwat (2010), conducted field experiments on the seasonal incidence of coccinellid beetles, Coccinella septempunctata Linnaeus and Menochilus sexmaculatus (Fabricius) on okra. The appearance of the beetles started from the first week of August and reached its maximum in the first week of October in both the years. Weather parameters (minimum temperature and relative humidity) showed significant negative correlation with coccinellid population, whereas, maximum temperature had non-significant positive and rainfall had non-significant negative correlation with coccinellid population.

f) Yield (q/ha)

Pooled data revealed that (Table 4), among the main plot treatments, July 15th transplanted crop registered significantly higher mean dry chilli yield of 3.74q/ha, which was on par with July 30th (3.56 q/ha), while the June 30th recorded least mean dry fruit yield of 2.75 q/ha. Among the different spacings significantly more dry chilli yield was observed in 90 X 60cm spacing (3.91q/ha) followed by 60 X 60cm (3.37 q/ha) and 75 X 45cm (3.10 q/ha) spacings, whereas the lowest chilli yield was recorded in 60 X 30cm (2.84 q/ha). The interaction effect between the main plot and subplots was found significant. Significantly highest mean chilli yield was registered in the combination of July 15th transplanted crop at 90 X 60cm (4.21 q/ha) followed by July 30th + 90 X 60cm (4.09 q/ha). Whereas, lowest chilli yield of 1.99 q/ha was registered in the combination of June 30th transplanted crop at 60 X 30cm treatment. The effect of planting date and spacing on yield of chilli has been indicated in UAS package of practices (Anon., 2004). But no information is available in relation to pest effect. Among the different treatments, The interaction effect between July 15th transplanted crop at 90 X 60cm was found to be the most cost effective by recording highest net return (Rs 15,921) followed by July 30th at 75 X 45cm (14,199) and June 30th at 90 X 60cm (13,133). Whereas August 15th transplanted plot at 60 X 30cm registered lowest net return of Rs 3,065/- (Table 5). By considering different

parameters, the treatments viz., July 15th planting at 90 X 60cm, June 30th at 90 X 60cm and August 15th at 90 X 60cm were found to be promising against chilli pests.

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Table 1 : Pooled Data of Effect of Date of Planting and Spacing on the Activity of Chilli Aphid M. Persicae

Sl. No.	Main plot\sub plot	Number of aphids/leaf														
		30 DAT					60 DAT					90 DAT				
		M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
1.	S_1	0.39 (1.12)	0.21 (0.96)	0.24 (0.99)	0.35 (1.09)	0.29c (1.04)	0.37 (1.11)	0.15 (0.89)	0.18 (0.92)	0.30 (1.05)	0.25c (1.00)	0.33 (1.07)	0.12 (0.85)	0.18 (0.92)	0.34 (1.08)	0.24c (0.99)
2.	S_2	0.50 (1.21)	0.25 (1.00)	0.29 (1.04)	0.34 (1.08)	0.34b (1.08)	0.45 (1.17)	0.21 (0.96)	0.25 (1.00)	0.29 (1.04)	0.30b (1.05)	0.31 (1.06)	0.16 (0.90)	0.19 (0.94)	0.31 (1.06)	0.24c (0.99)
3.	S_3	0.54 (1.23)	0.27 (1.02)	0.32 (1.07)	0.39 (1.12)	0.38b (1.12)	0.49 (1.20)	0.25 (1.00)	0.29 (1.04)	0.32 (1.07)	0.33b (1.07)	0.41 (1.14)	0.21 (0.96)	0.24 (0.99)	0.38 (1.12)	0.31b (1.06)
4.	S_4	0.74 (1.36)	0.31 (1.06)	0.38 (1.12)	0.54 (1.23)	0.49a (1.20)	0.71 (1.34)	0.29 (1.04)	0.35 (1.09)	0.51 (1.21)	0.46a (1.18)	0.65 (1.31)	0.27 (1.02)	0.26 (1.01)	0.45 (1.17)	0.40a (1.13)
Mean		0.54a (1.23)	0.26d (1.01)	0.30c (1.05)	0.40b (1.13)	0.37	0.50a (1.21)	0.22c (0.97)	0.26c (1.01)	0.35b (1.09)	0.33	0.42a (1.15)	0.19c (0.94)	0.21c (0.96)	0.37b (1.11)	0.29
For comparision of means		S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%		
Main (M)		0.027		0.075			0.025		0.071			0.023		0.063		
Sub (S)		0.011		0.029			0.010		0.026			0.009		0.025		
Interaction (MXS)		0.109		0.321			0.106		NS			0.103		0.291		
CV (%)		6.92					5.62					5.85				

M_1 (Month) – June 30th M_2 – July 15th M_3 – July 30th M_4 – August 15th
S_1 (Spacing) – 90 X 60cm S_2 – 60 X 60cm S_3 – 75 X 45 cm S_4 – 60 X 30 cm
In a column means followed by the same alphabet did not differ significantly by DMRT (0.05)

DAT : Days After Transplanting, figures in parenthesis are $\sqrt{x+0.5}$ transformed values
In a column means followed by the same alphabet did not differ significantly by DMRT (0.05)
Days After Transplanting,

Table 2 : Pooled Data of Effect of Date of Planting and Spacing on the Activity of Chilli Thrips S. Dorsalis

Sl. No.	Main plot\sub plot	Number of thrips/leaf														
		30 DAT					60 DAT					90 DAT				
		M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
1.	S_1	0.31 (1.06)	0.08 (0.78)	0.26 (1.01)	0.50 (1.21)	0.28b (1.03)	0.60 (1.27)	0.23 (0.98)	0.33 (1.07)	0.64 (1.30)	0.45b (1.17)	0.45 (1.17)	0.07 (0.76)	0.33 (1.07)	0.50 (1.21)	0.33b (1.07)
2.	S_2	0.37 (1.11)	0.14 (0.87)	0.29 (1.04)	0.55 (1.24)	0.33a (1.07)	0.51 (1.21)	0.21 (0.96)	0.35 (1.09)	0.66 (1.31)	0.43c (1.16)	0.43 (1.16)	0.09 (0.80)	0.33 (1.07)	0.56 (1.25)	0.35b (1.09)
3.	S_3	0.39 (1.12)	0.17 (0.91)	0.35 (1.09)	0.65 (1.31)	0.39a (1.12)	0.54 (1.23)	0.27 (1.02)	0.43 (1.16)	0.68 (1.32)	0.48b (1.19)	0.53 (1.23)	0.31 (1.06)	0.37 (1.11)	0.57 (1.25)	0.44a (1.16)
4.	S_4	0.81 (1.40)	0.27 (1.02)	0.39 (1.12)	0.72 (1.35)	0.24c (1.23)	0.89 (1.44)	0.31 (1.06)	0.37 (1.11)	0.71 (1.34)	0.57a (1.25)	0.73 (1.35)	0.27 (1.02)	0.29 (1.04)	0.47 (1.19)	0.43a (1.16)
Mean		0.47b (1.19)	0.16d (0.90)	0.32c (1.07)	0.60a (1.27)	0.38	0.63a (1.29)	0.25c (1.00)	0.37b (1.11)	0.67a (1.32)	0.48	0.53a (1.23)	0.18c (0.92)	0.33b (1.07)	0.52a (1.22)	0.39
For comparision of means		S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%		
Main (M)		0.030		0.084			0.032		0.089			0.029		0.076		
Sub (S)		0.016		0.044			0.019		0.053			0.015		0.039		
Interaction (MXS)		0.122		0.359			0.136		0.296			0.119		0.0289		
CV (%)		5.45					6.14					5.94				

M_1 (Month) – June 30th M_2 – July 15th M_3 – July 30th M_4 – August 15th
S_1 (Spacing) – 90 X 60cm S_2 – 60 X 60cm S_3 – 75 X 45 cm S_4 – 60 X 30 cm
In a column means followed by the same alphabet did not differ significantly by DMRT (0.05)
DAT : Days After Transplanting, figures in parenthesis are $\sqrt{x+0.5}$ transformed values

Table 3 : Pooled Data of Effect of Date of Planting and Spacing on the Activity of Chilli Mite, P. Latus and leaf Curl Index.

Sl. No.	Main plot\sub plot	Number of mites/leaf										leaf curl index									
		60 DAT					90 DAT					70 DAT					100 DAT				
		M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
1.	S_1	0.59 (1.27)	0.30 (1.05)	0.41 (1.14)	0.47 (1.19)	0.44c (1.16)	0.42 (1.15)	0.20 (0.95)	0.28 (1.03)	0.44 (1.16)	0.33bc (1.07)	0.74 (1.36)	0.25 (1.00)	0.32 (1.07)	0.45 (1.17)	0.44c (1.16)	0.79 (1.39)	0.26 (1.01)	0.31 (1.06)	0.52 (1.22)	0.47c (1.19)
2.	S_2	0.66 (1.31)	0.35 (1.09)	0.43 (1.16)	0.55 (1.25)	0.49ab (1.20)	0.46 (1.18)	0.24 (0.99)	0.31 (1.06)	0.48 (1.19)	0.37b (1.11)	0.85 (1.42)	0.31 (1.06)	0.35 (1.09)	0.56 (1.25)	0.52b (1.22)	0.89 (1.44)	0.27 (1.02)	0.36 (1.10)	0.60 (1.27)	0.53b (1.23)
3.	S_3	0.67 (1.32)	0.33 (1.07)	0.42 (1.15)	0.56 (1.25)	0.49ab (1.20)	0.43 (1.16)	0.29 (1.04)	0.30 (1.05)	0.47 (1.19)	0.37b (1.11)	0.87 (1.43)	0.26 (1.01)	0.37 (1.11)	0.59 (1.27)	0.52b (1.22)	0.88 (1.44)	0.31 (1.06)	0.43 (1.16)	0.66 (1.31)	0.57ab (1.25)
4.	S_4	0.94 (1.47)	0.46 (1.18)	0.53 (1.23)	0.69 (1.33)	0.65a (1.31)	0.72 (1.35)	0.41 (1.14)	0.52 (1.22)	0.62 ()1.29	0.56a (1.25)	0.94 (1.47)	0.38 (1.12)	0.45 (1.17)	0.71 (1.34)	0.62a (1.29)	1.06 (1.53)	0.32 (1.07)	0.56 (1.25)	0.72 (1.35)	0.67a (1.32)
Mean		0.71a (1.34)	0.36c (1.10)	0.44c (1.16)	0.56b (1.25)	0.51	0.50 (1.21)	0.28 (1.03)	0.35 (1.09)	0.50 (1.2)	0.40	0.85a (1.42)	0.30c (1.05)	0.37c (1.11)	0.58b (1.26)	0.53	0.91a (1.45)	0.29d (1.04)	0.42c (1.14)	0.63b (1.29)	0.56
For comparision of means		S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%		
Main (M)		0.037		0.098			0.043		0.125			0.029		0.059			0.034		0.089		
Sub (S)		0.024		0.080			0.025		0.076			0.018		0.034			0.022		0.056		
Interaction (MXS)		0.134		0.394			0.139		0.291			0.095		0.186			0.113		0.291		
CV (%)		756					7.35					8.83					9.05				

M_1 (Month) – June 30th M_2 – July 15th M_3 – July 30th M_4 – August 15th
S_1 (Spacing) – 90 X 60cm S_2 – 60 X 60cm S_3 – 75 X 45 cm S_4 – 60 X 30 cm
In a column means followed by the same alphabet did not differ significantly by DMRT (0.05)
DAT : Days After Transplanting, figures in parenthesis are $\sqrt{x+0.5}$ transformed values

Table 4 : Pooled data of effect of date of planting and spacing on the activity of natural enemies and yield

Sl. No.	Main plot\sub plot	Coccinellids/plant										Chrysopids/plant										Yield (q/ha)				
		60 DAT					90 DAT					60 DAT					90 DAT									
		M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
1.	S_1	0.95 (1.47)	1.20 (1.60)	1.16 (1.58)	0.97 (1.48)	1.07b (1.53)	0.98 (1.49)	1.26 (1.62)	1. 18 (1.59)	1.02 (1.51)	1.11c (1.55)	1.02 (1.02)	1.45 (1.45)	1.22 (1.22)	1.08 (1.08)	1.19c (1.19)	1.21 (1.21)	1.49 (1.49)	1.24 (1.24)	1.20 (1.20)	1.29 (1.29)	3.42	4.21	4.09	3.91	3.91a
2.	S_2	1.15 (1.57)	1.36 (1.67)	1.32 (1.65)	1.20 (1.60)	1.26a (1.62)	1.19 (1.59)	1.42 (1.69)	1.31 (1.64)	1.26 (1.62)	1.30b (1.64)	1.19 (1.19)	1.71 (1.71)	1.39 (1.39)	1.31 (1.31)	1.40a (1.40)	1.25 (1.25)	1.65 (1.65)	1.48 (1.48)	1.34 (1.34)	1.43 (1.43)	2.89	3.81	3.63	3.14	3.37b
3.	S_3	1.03 (1.51)	1.28 (1.63)	1.23 (1.61)	1.15 (1.57)	1.17ab (1.58)	1.11 (1.55)	1.32 (1.65)	1.29 (1.64)	1.13 (1.56)	1.21b (1.60)	1.13 (1.13)	1.60 (1.60)	1.38 (1.38)	1.20 (1.20)	1.33b (1.33)	1.20 (1.20)	1.66 (1.66)	1.40 (1.40)	1.29 (1.29)	1.39 (1.39)	2.72	3.50	3.32	2.88	3.10c
4.	S_4	1.27 (1.63)	1.50 (1.72)	1.43 (1.70)	1.35 (1.66)	1.39a (1.68)	1.29 (1.64)	1.52 (1.73)	1.48 (1.72)	1.40 (1.68)	1.42a (1.69)	1.35 (1.35)	1.71 (1.71)	1.56 (1.56)	1.55 (1.55)	1.54a (1.54)	1.39 (1.39)	1.71 (1.71)	1.59 (1.59)	1.49 (1.49)	1.55 (1.55)	1.99	3.43	3.22	2.74	2.84d
Mean		1.10c (1.55)	1.34a (1.66)	1.29a (1.63)	1.17b (1.58)	1.22	1.14c (1.57)	1.38a (1.67)	1.32a (1.65)	1.20b (1.60)	1.26	1.17c (1.17)	1.62a (1.62)	1.39b (1.39)	1.29b (1.29)	1.37	1.26c (1.26)	1.63a (1.63)	1.43a (1.43)	1.33b (1.33)	1.41	2.75c	3.74a	3.56a	3.17ab	3.30
For comparision of means		S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%			S Em±		CD at 5%		
Main (M)		0.098		0.285			0.103		0.294			0.119		0.341			0.121		0.341			0.121		0.319		
Sub (S)		0.134		0.389			0.141		0.385			0.195		0.561			0.112		0.294			0.253		0.616		
Interaction (MXS)		0.745		2.143			0.823		2.425			1.133		3.192			1.081		2.961			0.89		2.357		
CV (%)		6.16					6.23					9.85					8.41					7.15				

M_1 (Month) – June 30th M_2 – July 15th M_3 – July 30th M_4 – August 15th
S_1 (Spacing) – 90 X 60cm S_2 – 60 X 60cm S_3 – 75 X 45 cm S_4 – 60 X 30 cm
In a column means followed by the same alphabet did not differ significantly by DMRT (0.05)

Table 5 : Cost Economics of Chilli in Different Date of Planting and Spacing.

Sl. No	Treatment	Yield (q/ha)	Gross Returns (`/ha)	Total cost of production (`/ha)	Net Returns (`/ha)	C:B Ratio
1	M_1S_1	3.42	24190	11057	13133	1: 2.18
2	M_1S_2	2.89	21730	11356	10374	1:1.91
3	M_1S_3	2.72	22878	11482	11396	1:1.99
4	M_1S_4	1.99	16318	11613	4705	1:1.41
5	M_2S_1	4.21	26978	11057	15921	1:2.44
6	M_2S_2	3.81	23200	11356	11932	1:2.04
7	M_2S_3	3.50	24272	11482	12790	1:2.11
8	M_2S_4	3.43	17302	11613	5689	1:1.49
9	M_3S_1	4.09	25256	11057	14199	1:2.29
10	M_3S_2	3.63	21648	11356	10292	1:1.91
11	M_3S_3	3.32	22878	11482	11396	1:1.99
12	M_3S_4	3.22	17056	11613	5443	1;1.47
13	M_4S_1	3.91	22796	11057	11739	1:2.06
14	M_4S_2	3.14	20582	11356	9226	1:1.81
15	M_4S_3	2.88	21812	11482	10330	1:1.90
16	M_4S_4	2.74	14678	11613	3065	1:1.26

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Potential of Botanical Lures as Attractant for Monitoring Grasshoppers (Orthoptera) on Yam (Dioscorea Rotundata) Plant in Makurdi, Benue State, Nigeria

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The attractants are cheap, non toxic to users and environment, easy to manage by farmers, easy to control fast flying and very alert insects such as the Acrididae.

Keywords: botanical lures, attractants, grasshoppers, yam (dioscorea rotundata), monitoring, control.

GJSFR-D Classification : FOR Code: 079999

Strictly as per the compliance and regulations of :

Potential of Botanical Lures as Attractant for Monitoring Grasshoppers (Orthoptera) on Yam (Dioscorea Rotundata) Plant in Makurdi, Benue State, Nigeria

Eunice Okoroafor

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I. Introduction

Grasshoppers are pests of sorghum, maize, rice, oil palm, vegetables,and millets in Nigeria (Amatobi, 2007). Species such as Catantops melanosticus schaum (Orthoptera: Acrididae), Pyrgomorpha vignaudi Geur (Orhoptera: Pyrgomor-phidae) and Homorocoryphus nitidulus Walker (Orthoptera: Tettigonidae) are recorded as pests of crops in Nigeria (Amatobi, 2007; Wood and Ambridge, 1996). Previous control measures reported include hand-picking and chemical control with Pyrethroids (Karate, Cymbush) and organophosphate such as fenitrothion. These chemicals are uneconomical and ineffective for controlling members of acrididae that are fast flying and very alert (Critchley, 2001). Although grass hoppers are not the major insect on yam crop,but the feeding on the leaves is a signal for preference and concern for future. The monitoring of these minor pests on yam is important in order to establish the population density in yam field. Yams are food crops of major importance in tropical agriculture and constitutes an average of 32% of farmers' gross income derived from arable crops (Orkwor, 1998). It is also a major source of carbohydrate and are eaten in large quantities in Nigeria where they are utilized in various ways. Most of the carbohydrate is amylopectin starch. The carbohydrate content in D. rotundata is 61% ,60 – 70% moisture, 1% fat, 1.1 – 2% crude protein, 0.4 – 0.8% crude fibre, 0.7 – 2.6% ash, 6 – 12 meg/100g vitamin C and 0.8 meg/100g vitamin A (Onwueme, 1987). It can be eaten boiled, fried, pounded. Other processed form includes flour for 'fufu' and bakery. Yams are significant sources of calories, calcium, nicotinic acid, iron, thiamine, and ascorbic acid (vitamin C), which concentrate in the bulbous region and under the skin (Coursey, 1967).

There are a number of constraints to yam production which include high cost of pesticides for insect and disease control. The feeding of grasshopper on yam leaves cause leaf perforations leading to reduced leaf surface area for photosynthesis. The damage done by grasshoppers on yam leaf has not been quantified but severe leaf ragging can lead to stand loss and drastic reduction of tuber yield . The objectives of this research were to Investigate the trapping potential and longevity of these botanical lures in the field.

II. Materials and Methods

The field experiments were conducted in 2004, 2005 and 2006 cropping seasons at Mbagune village, Makurdi L. G. A., six kilometer to the University of Agriculture campus Makurdi, (Latitude 7oN, Longitude 8oE).

a) Description of Trap

The trap had two components, the plastic bowl which contained the plant extract as lure and a plastic table which served as rain protectant to the extract lure. Aqueous extract of three types of legume prepared at 25% w/v and 50% w/v concentrations respectively were

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used as lure along with aqueous organic product from poultry in each of the trap.A control trap was also filled with water, The height of the plastic table was 24 cm with surface area of 615.83cm2. The table had four stands with four openings of 21 cm wide between the stands as point of entry for insects. The plastic bowl containing the lure had depth of 12cm and surface area of 452.4cm2. This is the first report on this type of trap with natural lure (Plate 1). Traps with baits were mounted between heaps in a plot of cultivated yam (D. rotundata Poir cv Amula) according to treatment allocation to plots.

b) Planting and trap placement

The land was cleared, marked and mounds were made. The plots were planted with Dioscorea rotundata cultivar Amula on first week of May. The weight range of yam setts planted was between 50-100g. The plots were weeded three times starting from eight weeks after planting. Compound fertilizer (NPK 20:10:10) was applied at the rate of 100kg/ha using ring application method at 10 weeks after planting (WAP). The traps were placed in the plots in mid-July and the trapping of the beetles in extracts terminated on the third day of September. The mounted traps were removed from the plots at the end of October each year. Traps were spaced at 20cm between plots and 45cm between replicates. Old extracts were replaced with fresh one at the fifth week of trap placement, thus, the longevity of the plant extract was four weeks. Harvesting was carried out at the second week of December (28 weeks after planning) when yam leaves turned to yellowish to brown colour.

c) Data Collection and Statistical Analysis

Data collection on the number of grasshoppers species trapped commenced from 23rd July to 3rd September for three years. Grasshopper species were sighted 24 hours after trap placement in the field and was noted as day one. Data with zero means were transformed using square root transformation before the analysis of variance.. The grasshopper species were collected weekly(Plates 2 and 3), rinsed with water and the number captured per week was recorded and pinned up using entomological pins in insect box and identified at the Insect Museum of the Department of Crop Protection, Institute for Agricultural Research (IAR), Samaru, Ahmadu Bello University, Zaria. Data obtained in 2004, 2005 and 2006 were analyzed using Analysis Of Variance (ANOVA) with SAS software version 8 (SAS, 2000) for split plot and means were separated using Student Newman Kuels test (SNK-test) at 5% level of significance. The cumulative means of seven days interval trap catches were calculated for seven weeks and used to plot graphs.

III. Results and Discussion

The cover trap technique was more effective than the uncover technique, and Prolure significantly ($P<0.05$) trapped more grasshoppers than Pklure in 2004 (Table 1).Thus the cover trap was selected for the experiment in 2005 and 2006 cropping seasons.

Prolure significantly ($P<0.05$) trapped the grasshopper species compared with the PKlure, CPlure and Pflure in 2005 and 2006 wet seasons (Tables 2 and 3, Plate 2).

Irrespective of the treatment sources, 50%W/V concentration of the different lures significantly ($P<0.05$) trapped the grasshopper species compared with 25%W/V concentration (Tables, 2 and 3). However, Prolure was best. The peak period of catches recorded was 6th August in 2005 and 30th July to 6th August in 2006 cropping seasons. There was moderate wind-force on scale 2.69- 3 in 2004 -2006 in the month of August (Table 4) when the peak number of grasshoppers was recorded.This may imply that high windforce above scale 3 might reduce the trapping of grasshoppers in the presence of an effective attractant.

The effect of these botanical lures on grasshopper behaviour is similar to the visual and olfactory cues reported on western pine beetle by Strom et al (2001). The botanical lures induced attraction of grasshoppers compared with zero trap in control treatment (water). Grasshopper response was dose dependent as increase in dose of lures resulted in an increase in attraction. The lures might contain some stimulant components that evoked a quick directional response in receptive grasshoppers thus, attraction of the grasshoppers in this study might be due to olfalctory cue.

IV. Conclusion

Three botanical aqueous lure namely Prolure,, Pklure, Cplure were investigated along with an organic product Pflure for their potential as attractant for trapping insects. The results indicated that Prolure was the best attractant compared with others. Grasshoppers response was dose dependent as increase in dose of lures resulted in an increase in attraction. Further research work to investigate the active components of the test materials that is responsible for attraction is crucial.

Plate 1 : Insect Monitoring Trap

Plate 2 : Grasshoppers trapped in degraded Prolure

Plate 3 : Grasshoppers trapped in fresh Prolure

Table 1: Comparison of the mean (±SE) number of grasshoppers trapped in Botanical Lures using two trapping Techniques in 2004 cropping season

Treatments	10 WAP(23rd July)	11 WAP(30th July)	12 WAP(6th August)
50% Prolure Cover	5.00±2.00	10.66±3.05	6.68±2.08
50% Prolure Uncover	3.66±0.57	6.66±3.05	4.00±1.00
50% PKlure Uncover	2.66±0.08	8.66±1.52	2.00±1.00
50% PKlure Cover	5.33±2.08	13.00±2.64	3.00±1.20
Control	0.50±0.00	0.50±0.00	0.50±0.00

Wap=weeks after planting

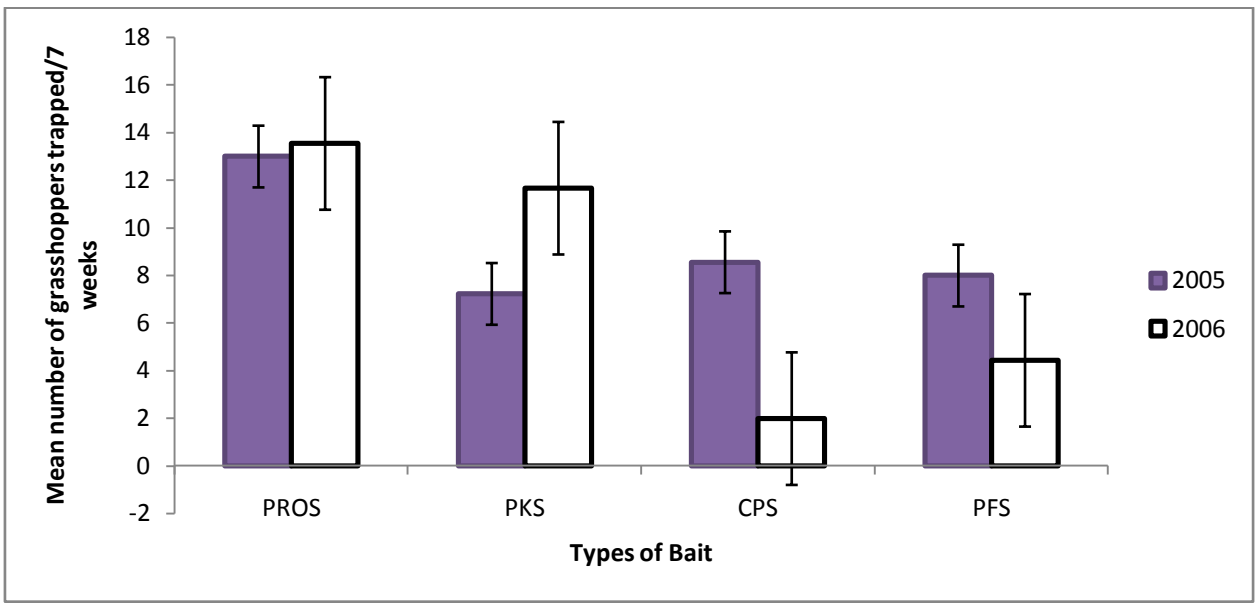

Fig.1 : Comparison of mean number of Grasshoppers trapped with PROS= PROlure ,PKS= PKlure, CPS=CPlure and PFlure in 2005 and 2006 cropping seasons

Table 2 : Comparison of the mean (±SE) number of grasshoppers trapped at different concentrations of Botanical lures in 2005

Table 2: Comparison of the mean (±SE) number of grasshoppers trapped at different concentrations of Botanical lures in 2005.

	23 July (10 WAP)		
Treatments		Concentration (%)	
0	25	50	
Prolure	0.50± 0	1.29 ± 0.50	1.90 ± 0.55
Pklure	0.50 ± 0	1.05 ± 0.29	1.86 ± 0.27
CPlure	0.50 ± 0	0.50 ± 0.00	1.34 ± 0.20
PFlure	0.50 ± 0	1.27 ± 0.58	1.46 ± 0.20
6 Aug (12 WAP)			
		Concentration (%)	
	0	25	50
Prolure	0.50± 0	1.46 ± 0.20	1.64 ± 0.45
Pklure	0.50 ± 0	1.87 ± 0.29	1.77 ± 0.16
CPlure	0.50 ± 0	0.76 ± 0.31	2.09 ± 0.84
PFlure	0.50 ± 0	1.59 ± 0.65	1.76 ± 0.31
	27 Aug (15 WAP)		
Treatments		Concentration (%)	
	0	25	50
Prolure	0.50 ± 0	1.17 ± 0.43	1.76 ± 0.31
Pklure	0.50 ± 0	1.34 ± 0.26	1.46 ± 0.20
CPlure	0.50 ± 0	0.50 ± 0 .00	1.28 ± 0.50
PFlure	0.50 ± 0	1.84 ± 0.44	1.17 ± 0.43

Table 3 : Comparison of the mean (±SE) number of grasshoppers trapped at different concentrations of Botanical lures in 2006

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	July 23 (10 WAP)		
Treatments		Concentration (%)	
	0	25	50
Prolure	0.50±0.00	2.28 ± 0.39	0.50 ± 0.00
Pklure	0.50±0.00	1.47 ± 0.51	1.32 ± 1.06
CPlure	0.50±0.00	1.09 ± 0.67	1.90 ± 0.55
PFlure	0.50±0.00	1.09 ± 0.67	1.67 ± 0.16
	6 Aug (12 WAP)		
		Concentration(%)	
Treatments	0	25	50
Prolure	0.50 ±0.00	2.06 ± 0.60	1.72 ± 0.88
Pklure	0.50 ±0.00	1.09 ± 0.67	1.54 ± 0.81
CPlure	0.50 ±0.00	0.87 ± 0 .29	1.09 ± 0.67
PFlure	0.50 ±0.00	1.44 ± 0.37	2.08 ± 0.86
	27 Aug (15 WAP)		
		Concentration(%)	
Treatments	0	25	50
Prolure	0.50 ± 0.00	1.25 ± 0.94	1.47 ± 0.71
Pklure	0.50 ± 0.00	1.46 ± 1.46	0.99 ± 0.50
CPlure	0.50 ± 0.00	0.99 ± 0.50	0.99 ± 0.50
PFlure	0.50 ± 0.00	1.44 ± 0.37	1.47 ± 0.71

Pros(prolure),Pks(pklure),Cps(Cplure),Pfs(Pflure)

Table 4 : Meteorological Data

MONTH	RAINFALL (MM)			WIND-SPEED(KM)			WIND-FORCE(scale 1 - 6)		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
July	239	284.4	185.8	104.10	97.90	89.46	2.81	2.67	2.81
August	370.2	263.4	415.2	99.37	76.99	106.9	2.93	2.69	3
Sept	325.79	314.8	252.2	83.2	20.88	105.06	3	3.3	2.46
Oct	293.8	183.2	207.2	762.3	65.62	87.96	1.6	2.12	1.67

Source: Meteorological Station, Air force Base, Makurdi.

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Landing Trends, Species Composition and Percentage Composition of Sharks and Rays in Chittagong and Cox's Bazar, Bangladesh

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Abstract- The study was conducted from April, 2006 to June, 2010 on landing trends, species composition and percent contribution of sharks and rays by weight using the catch records of Marine Fisheries Survey Management Unit, Chittagong from two landing centers Fishery ghat, Chittagong and BFDC ghat, Cox's Bazar. This study identified 27 species in total representing 11 species of shark (04 families) and 16 species of ray (09 families). The highest landing volume (134 MT) and contribution (76%) to total catch for the whole sampling period was found from Scoliodon laticaudus followed by Rhizoprionodon acutus (108 MT or 55%), Carcharhinus melanopterus (75 MT or 38%), Sphyrna zygaena (49 MT or 26%), Chiloscyllium indicum (38 MT or 20%), Eusphyra blochii (22 MT or 11%) Galeocerdo cuvier (21 MT or 10%) and other (03 MT or 2%). Species which occurred least were placed in the 'other' category comprising Carcharhinus amblyrhynchos, Stegostoma fasciatum, Carcharhinus leucas and C. falcifomis.

Keywords: shark, ray, species composition, elasmobran-ches fishery, landing trend, catch data, abundance, percent contribution.

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Landing Trends, Species Composition and Percentage Composition of Sharks and Rays in Chittagong and Cox's Bazar, Bangladesh

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Abstract- The study was conducted from April, 2006 to June, 2010 on landing trends, species composition and percent contribution of sharks and rays by weight using the catch records of Marine Fisheries Survey Management Unit, Chittagong from two landing centers Fishery ghat, Chittagong and BFDC ghat, Cox's Bazar. This study identified 27 species in total representing 11 species of shark (04 families) and 16 species of ray (09 families). The highest landing volume (134 MT) and contribution (76%) to total catch for the whole sampling period was found from Scoliodon laticaudus followed by Rhizoprionodon acutus (108 MT or 55%), Carcharhinus melanopterus (75 MT or 38%), Sphyrna zygaena (49 MT or 26%), Chiloscyllium indicum (38 MT or 20%), Eusphyra blochii (22 MT or 11%) Galeocerdo cuvier (21 MT or 10%) and other (03 MT or 2%). Species which occurred least were placed in the 'other' category comprising Carcharhinus amblyrhynchos, Stegostoma fasciatum, Carcharhinus leucas and C. falciformis. Among rays, the landing volume and resultant percent contribution to overall catch found highest from Himantura uarnak (219 MT, 120%), followed by Himantura walga (158 MT or 60%), Himantura bleekeri (68 MT or 34%), Rhinobatos granulatus (29 MT or 18%), Gymnura micrura (12 MT or 7%) Mobula diabolus (11 MT or 5%), Rhynchobatus djiddensis (10 MT or 5%), Aetomylaeus nichofii (9 MT or 4%), Rhinoptera javanica (8 MT or 4%) and Narcine timlei (7 MT or 4%) and other species with least occurrence (5 MT or 4%). Species in other category consisted of Gymnura poecilura, Rhina ancylostoma, Himatura gerrardi, Anoxypristis cuspidata, Himantura undulata and Taeniura. Sps. Landing of different species were found to vary from month to month and year to year throughout the sampling period. To make absolute comment regarding these trends of occurrence, base line biological information together with long term catch record for size distribution was needed which could not be work out from the present data set. However, total landing of sharks and rays were found to be on slight decline.

Keywords: shark, ray, species composition, elasmobranches fishery, landing trend, catch data, abundance, percent contribution.

I. Introduction

Bangladesh has a long coastline of 714 km and comprising an Exclusive Economic Zone (EEZ) of 164,000 sq. km. About 44 percent of our EEZ consists of continental shelf providing a rich resource of coastal fisheries. In Bangladesh economy, fisheries sector plays a significant role through generating employment and providing major source of animal protein for the population. Shark fishery is largely artisanal, multi gear and multispecies fishery in Bangladesh which occurs from the coasts to the edges of the EEZ. Sharks and rays come mostly as by catch but in recent years, some shark targeted boats are introduced. The contribution of sharks and rays is only 1% of our total marine landings. There are a range of gears to harvest sharks but caught by shark net (modified gill net) and rays are mainly caught by hook and lines. Besides, rays are also harvested as incidental catch by set bag net and trammel net. In addition, large number of small size rays (juveniles or just born) and sharks caught by shrimp trawl net remains unreported.

Traditionally, elasmobranches have never been highly prized fish product. Their economic value ranks low among marine commercial fisheries. For example, in the Taiwanese gill net fisheries of the central Western Pacific, shark trunk prices attain only 20% and 60 % of those of Tunas and Mackerels respectively (Millington, 1981). The only valued elasmobranches product is shark fin for oriental soup, a commodity which recently has attained a considerable increase in demand (Cook, 1990). In our country, shark fins and ray skin are usually processed for export market and the meat part is sold for local consumption mostly to the tribal community. However, fins of small sized shark have no export value and therefore sold as raw meat or in dried condition.

Recently, number of shark fishing boats, fishing days and export trade have been expanding rapidly which gives some cause of alarm. Moreover, catch of small size or juvenile sharks and rays has increased with the decrease of large size sharks reminding us that the stock may be undergoing overexploitation (Halder, 2010). In Bangladesh, landing of shark is not reported by species but by groups i.e. sharks and rays in yearly statistical report by the Department of Fisheries. Species wise catch data is very important to know the catch composition, pattern of occurrence and to identify the species under threat. Sharks are widely recognized as being vulnerable to over fishing because they grow slowly, are late to mature and produce relatively few young. As a result, they are susceptible to over fishing

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and slow to recover. Therefore, there has been a realization that the stocks may be overfished and some management initiatives are required. In the present study, effort has been made to determine the landing trends, species composition and percent contribution of sharks and rays from April 2006 to June 2010 in the coasts of Chittagong and Cox's Bazar. It is expected that the statistical interpretation would rightly focus on the status of the resources and contribute towards any national management plan for shark fishery of this country.

II. Materials and Methods

a) Sampling Stations

The study was under taken for about 04 years starting from April 2006 up to June 2010 at two fish landing centers i.e. BFDC ghat of Cox's Bazar district and Fishery ghat of Chittagong district situated at the south-eastern part of the Bay of Bengal. These two landing centers were selected because the major landing of shark and ray is done here and the wholesale and retail market is also located in these two places.

b) Data Collection and Statistical Analysis

Species wise landing data were recorded both at landing stations and on board commercial fishing vessels. Data were collected from four field visits per month i.e. new-moon, full-moon, first quarter and last quarter. The species were preserved in 5% formalin just after collection from the landing centers and then sorted in the laboratory of Marine Fisheries Survey Management Unit (MFSMU), Chittagong, Bangladesh. Species were identified to the lowest possible taxonomic position by consulting the following resources: Rahman et al. (2009), Albert et al. (2007), Kazunari et al. (2007), Raje et al. (2007), Ramon (1994), Quddus et al. (1988), FAO (1984), Munro (1982), Day (1978) and Hussain (1972).

Sampling was performed through interviews with the Arartdar (assemblers), boat owners and fishermen of the boat. Information was collected on trip duration per month, number of fishing days and fishing effort. The length (total length for shark and disc width length for ray) and weight of the fishes were measured directly by using balance and measuring tape. The percentage contributions of shark and ray species were calculated by weight. The species wise weight was measured in kilogram and then it was converted into metric tons (MT). Data processing and analysis was done by MS Excel.

III. Result

a) Description of Boats and Gears

Sharks and rays usually come as the commercial catch of artisanal mechanized fishing boats. In Cox's Bazar and Chittagong, about 50-60 boats are engaged for fishing which are typical open hulled wooden boats of 5-7 meters long with engines of 45-65/75 Hp. Each boat carries 17-18 fishermen and their active fishing days last for 15-18 days depending on the volume of the catch. The main gears include shark net (gill net), set bag net (ESBN and MSBN), long lines and trammel net. Shark nets are large mesh gill net made of thread no.4 and having length, depth and mesh size of 1500-3000 m, 10-15 m and 450 mm respectively. Long lines are mainly used for rays consist of a nylon monofilament mainline of 2 to 3 mm in diameter hung in a sagging curve between surface float. The branch lines with a length of 5-12 m descend from the main line, each terminating in a single baited 'J' hook. The number of hooks ranges from 800-6000 and hook size varies from No.6-11. Frozen squids (Loligo spp.) and cuttle fish (Sepia spp.) and sardines (Sardinella spp.) are commonly used as bait. Both long lines and gill nets are shot in the evening and their retrieval begins after midnight.

b) Total Landing and Species Composition

A total of 11 species of sharks (04 families) and 16 species of rays (09 families) were identified from the present study (Table 1). According to total landing, the most common and widely distributed shark species were found as Scolioden laticaudus, Rhizoprionodon acutus, Carcharhinus melanopterus, Sphyrna zygaena and Chiloscyllum indicum (Fig. 1). The relatively common species were Eusphyrna blochii and Galeocerdo cuvier while the least common or rare shark species in the catch were Carcharhinus amblyrhynchos, Stegostoma fasciatum, Carcharhinus leucas and C. falcifomis. Likewise, the most abundant ray species were found as Himantura uarnak, H. walga, H. bleekeri and Rhinobatos granulatus. The relatively common ray species in the catch were Gymnura micrura, Mobula diabolus, Rhynchobatus djiddensis, Aetomylaeus nichofii, Rhinoptera javanica and Narcine timlei (Fig. 2). The species with least occurrence throughout the sampling period were Gymnura poecilura, Rhina ancylostoma, Himatura gerrardi, Anoxypristis cuspidata, Himantura undulata and Taeniura. Sps. Fig. 3 shows year wise total landings of sharks and rays during the sampling period and it appears to be on slight decline.

c) Average Size of Species

In the present investigation, an attempt had been made to record the size of different shark and ray species but it did not cover all. However, the average size of the dominant shark species were found as follows: Scoliodon laticaudus (average size of 50-52 cm and 0.15-0.2 kg), Rhizoprionodon acutus (52-90 cm and <1.5 kg), Carcharhinus melanopterus (68 cm and 1.53 kg), Sphyrna zygaena (55-75 cm and 1.5-2.5 kg), Chiloscyllium indicum (22-33 cm and 0.15-1.5 kg), Eusphyrna blochii (>60 cm and 1.5-2 kg) and Galeocerdo cuvier (54-77 cm and 2-15 kg). The average size of the dominant ray species were found as follows:

Himantura uarnak (average disc width 92 cm and weight 56 kg), Himantura walga (28 cm and 0.15-15 kg), Himantura bleekeri (92 cm) and Rhinobatos granulatus (up to 107 cm and 2-2.5 kg).

d) Percent Contribution of Species

Species wise percent contribution to total landings during the sampling period is shown in table 1. Among sharks, the greatest contribution (76%) came from Scoliodon laticaudus (Fig. 4) followed by Rhizoprionodon acutus (55%), Carcharhinus melanopterus (38%), Sphyrna zygaena (26%), Chiloscyllium indicum (20%), Eusphyrna blochii (11%), Galeocerdo cuvier (10%) and other (2%). Similarly, Fig. 5 shows that among rays, the major contribution was from Himantura uarnak (120%) followed by Himantura walga (60%), Himantura bleekeri (34%), Rhinobatos granulatus (18%), Gymnura micrura (7%), Mobula diabolus (11 MT, 5%), Rhynchobatus djiddensis (10 MT, 5%), Aetomylaeus nichofii (09 MT, 4%), Rhinoptera javanica (08 MT, 4%) and Narcine timlei (07 MT, 4%) and other species with least occurrence (08 MT, 4%). Species which were rare in the catch or constituted very low proportion are placed in 'other' category.

e) Landing Trend of Different Species

The landing patterns of the shark and ray species most commonly found in this study are presented below:

During April-June/2006, the highest and lowest percentage composition of Scoliodon laticaudus was 46.41% and 6.37% in the month of May and June/06 respectively. In 2006-07, the dominant percentage was 48.30% in the month of August/06 and the lowest was 1.49% in February/07. During 2007-2008, the highest and lowest percentages were 26.20% in May/08 and 1.38% in June/08 respectively. In 2008-09, the maximum and minimum percentages were 53.67% and 3.31% during December/08 and October/08. During 2009-2010, the highest percentage was 63.89% in September/09 and the lowest was 4.34% in May/2010 respectively (Fig. 6). During April-June/2006, the highest percentage composition of Rhizoprionodon acutus was 50.80% and lowest was 3.75% in the month of April/06 and June/06 respectively. During 2006-2007, the highest and lowest percentages were 27.25% and 0.41% in July/06 and January/07 respectively. In the period 2007-2008, the maximum percentage was 46.29% in the month of September/07 and the minimum was 2.71% in January/08. During 2008-09, the dominant and lowest catches were 25.35% and 0.85% in March/09 and September/08 respectively. In the year 2009-2010, the maximum and minimum percentages were 15.07% and 0.22% in the month of August/09 and May/10 respectively (Fig. 7).

During April-June/2006, the landing of Carcharhinus melanopterus species was zero. In 2006 to 2007, the highest and lowest percentage compositions were 21.75% and 1.14% in the month of June/07 and January/07 respectively. During 07-08, the maximum abundance was 28.84% in the month of August/07 and minimum was 2.14% in September/07. In 2008-09, the dominant and lowest catches were 35.65% and 0.49% in the month of April/09 and December/08 respectively. During 2009-10, the highest percentage was 52.24% in the month of May/10 and lowest was 0.66% in October/09 (Fig. 8). During April-June/2006, the percentage composition of Sphyrna zygaena was 0.33% only in the month June/06. In 2006-07, the highest and lowest percentages were 7.67% and 0.68% in the month of June/07 and March/07 respectively. During 2008-2009, the maximum catch percentage was 14.09% in the month of February/09 and minimum was 2.51% in March/09. In 2009-2010, the dominant and lowest percentages were 21.35% and 1.42% in the month of March/10 and October/09 respectively (Fig. 9).

During April-June/2006, the percentage compositions of Chiloscyllium indicum were 4.95% and 2.78% in the month of June/06 and May/06 respectively. In the year 2006-07, the highest and lowest percentages were 27.32% and 0.10% in May/07 and August/06 respectively. During 2007-08, the maximum catch percentage was 12.23% in the month of April/08 and the minimum was 0.61% in September/07. In 2008-09, the dominant catch was 14.41% in February/09 and the lowest in the month of May/09 was 0.53%. During 2009-10, the maximum and minimum catch percentages were 11.31% and 0.21% in the month of June/10 and February/10 respectively (Fig. 10).

During April-June/2006, the percentage compositions of Himantura uarnak catch were 83.21% and 13.41% in the month of June/06 and May/06 respectively. In 2006-07, the highest percentage was 65.44% in March/06 and the lowest was 5.57% in the month of February/07. During 2007-08, the maximum and minimum landings were 25.49% and 0.04% in the month of December/07 and September/07 respectively. In 2008-09, the dominant catch was 27.35% in the month of January/09 and the lowest was 0.53% in December/08. During 2009-10, the highest and lowest percentage compositions were 18.30% and 0.23% in the month of February/10 and June/10 respectively (Fig. 11). The percentage composition of Himantura walga landing was absent during April-June/2006. In 2006-07, the dominant and lowest compositions were 60.66% and 0.22% in the month of February/07 and October/06 respectively. During 2007-08, the maximum catch percentage was 29.65% in September/07 and the minimum was 5.34% in the month of April/08. In 2008-09, the dominant percentage composition was 11.12% in the month of June/09 and the lowest was 0.62% in July/08. During 2009-10, the highest and lowest catch percent were 16.93% and 0.33% in the month of July/09 and November/09 respectively (Fig. 12).

During April-June/2006, the percentage composition of Himantura bleekeri was totally absent. In 2006-07, the highest catch percentage was 17.07% in February/07 and the lowest was 0.08% in April/07. During 07-08, the maximum and minimum landings were 34.87% and 0.48% in the month of October/07 and April/08 respectively. In 2008-09, the dominant percentage was 55.99% in the month of September/08 and the lowest was 2.23% in November/07. During 2009-10, the highest and lowest percentage compositions were 34.66% and 0.21% in the month of October/09 and February/10 respectively (Fig. 13). During April-June/2006, the percentage compositions of Rhibobatos granulatus were 16.29% and 0.27% in the month of May/06 and June/06 respectively. In the year 2006-07, the maximum percentage was 7.97% in November/06 and the minimum was 0.19% in the month of September/06. During 2007-08, the dominant and lowest percentages were 24.01% and 0.60% in the month of June/08 and April/08 respectively. In 2008-09, the highest percentage was 7.97% in the month of November/08 and lowest was 0.36% in June/09. During 2009-10, the maximum and minimum percentage compositions were 36.91% and 0.20% in the month of April/10 and June/10 respectively (Fig. 14).

IV. Discussion

From the survey report by White et al. (1985), it appears that maximum number of sharks and rays are distributed and harvested between 10-50 meter depth zones of the Bay of Bengal. In the present study, major landings came from the artisanal mechanized boats, so it can be predicted that most sharks and rays were caught within 40 meter depth. It should be noted that shark target fishing has been developed for the last 5-10 years mainly by using hooks and lines during winter months. During 2007- 2008, about 53% of total shark and ray landings were caught by gill net (shark net) followed by hook and lines (34%) and trammel net (8%) and the minimal catch was from set bag net i.e. 5% (Fisheries Statistical Yearbook of Bangladesh, DoF, 2009).

In the present investigation, 11 species of shark and 16 species of ray were identified (Table 1). The number of shark and ray species in Bangladesh reported by different authors varies. According to IUCN (2000), the total number is 56, while Rahman et al. (2009), Roy et al. (2007), Quddus et al. (1988), Day (1978) and Hussain (1970) mentioned the number as 51, 22, 21, 63 and 56 respectively. For proper identification of species, publication of detail species profile in vernacular language is very important (Halder, 2010). Besides, the scientific names and even family names of many Chondrichthyes species has been changed which needs to be upgraded to avoid mistakes. Cantor (1849) published a catalogue, which outlines the taxonomy of 28 species of sharks and rays in Malaysian waters, while Scott (1959) described some 294 marine fishes, out of which 25 are sharks and rays. Ahmad et al. (1999) believed at least 12 families of sharks (comprising around 48 species) and 11 families of rays (41 species) inhabit in Malaysian waters. About 70 species of sharks occur in Indian seas within which about 22 species have only limited occurrence and value; around 12 are moderately abundant though not frequently caught and only 06 are major species in the fishery (Hanfee, 1998).

Halder (2010) showed that the average weight of sharks in Bangladesh ranged from 0.11 to 9.02 kg following the data of Roy et al. (2007) and commented that comparatively smaller sizes of sharks are caught here. In the present investigation, dominance of smaller size sharks was also observed which is due to the fact that 76% of the overall catch constituted by S. laticaudus (Fig. 4) having average size between 50-52 cm in total length and 0.15-0.2 kg in weight. Since, pelagic requiem sharks (e.g. Carcharhinus Sps.) of larger size are mostly common in offshore water which is beyond the reach of our artisanal fishermen; it is more likely that sharks more than 100 kg are rare in the catch. Further study on species size distribution through time and area need to be done to understand the issue of overexploitation. The country annual catch of sharks and rays in 2006-07, 2007-08, 2008-09 and 2009-10 were 4790 MT, 4767 MT, 3933 MT and 4033MT respectively (Fisheries Statistical Yearbook of Bangladesh, DoF, 2010). In the present study, the total landings in Chittagong and Cox's Bazar for the consecutive years were found as 342 MT, 188 MT, 181 MT and 172 MT respectively (Fig. 3), which corresponds to the slightly declining trend of the total country catch. However, to understand the actual trend in shark catches, no less than 15-20 years data set is required, nevertheless, the present findings has at least provided some initial ideas.

According to landing volume and contribution to overall catch, Scoliodon laticaudus was found to be the most common shark followed by Rhizoprionodon acutus (Fig. e 4) which is in agreement with the findings in Indian seas by Hanfee, (1998). He reported that among the requiem sharks, Carcharhinus sorrah, C. limbatus and C. melanopterus and the hammerhead shark Sphyrna lewini are common but in present study only C. melanopterus were common. He found that other sharks which occur moderately in the catches are the grey sharks, C. macloti, C. hemiodon, C. dussumieri, C. Sealei, Loxodon macrorhinus and Rhizoprionodon oligolinx but none of these were found to occur in the present study. Further, the tiger shark (Galeocerdo cuvier) and the hammerhead shark Eusphyra blochii were relatively common in the catches of sampling time which also agree with the findings of Hanfee. No similar work in the Bay of Bengal is available to compare with the present findings. However, the least common

species in the catch gives cause for some concern and requires investigation on their population status. It should be noted that changes in species contribution takes long time and require many years data to draw conclusion. Further, there may be other factors like changes in fishing effort and fishing practices having significant influence on catch. Catches in the exploratory surveys by the government of Indian tuna long liners showing that the Pelagic sharks constitute 42% in the Arabian Sea, 36% in the Bay of Bengal, 43% in the Andaman Sea and 31% in equatorial areas. However, there has been no organized industrial fishing for the pelagic sharks till now (Devadoss, 1997). Sivasubramaniam (1987) summarizes data from fisheries survey of Indian tuna research cruises off the south west coast of India during 1983-1986. These results indicate the catch rates of 17.6 sharks/1000 hooks. James and Pillai (1987) review additional research cruise result from areas of the south east Arabian Sea, Andaman Sea, Western Bay of Bengal and the equatorial region of Indian Ocean. They found the percentage contribution of sharks to the total catch average as 39.8%.

In Bangladesh, shark fishing is done throughout the year but the main season is November to March and a peak was found in June (Roy et al., 2007). In the present study, catch compositions varied from month to month of a sampling year (Fig 6 to Fig. 14). To interpret these patterns of occurrence, baseline biological information (such as life cycle, size composition, breeding behavior, food and feeding habit, age at birth, age of maturity, fecundity, growth, habitat, migration etc.) is needed. Besides, size class distribution was not possible to work out from the catch data which has an important bearing on the trends in occurrence. Pepperell (1992) analyzed the records of shark captures from 1961 to 1990 by game fish anglers off south-eastern Australia. He found interesting changes in size distribution of the catch that have occurred for blue, hammerhead, grey nurse, mako, tiger and white sharks caught over the past three decades. It should be mentioned that MFSMU of Chittagong started to record species wise catch data of elasmobranches since 2005 for the landing stations in Chittagong and Cox's Bazar while such record is not available for the landing centers at south west part of Bangladesh. Besides, many species of sharks and rays are highly seasonal and erratic in their occurrence i.e. vary over geographical locations, therefore, country wide and regional catch record is very important to track changes in elasmobranches diversity.

James (1973) elaborated the occurrence of some shark and ray species off the east coast of India. He reported that S. laticaudus breeds round the year, therefore dominates the catch which is in agreement with present findings (Fig. 6). He found that C. melanopterus was quite common in the catch from April-July which matches the present findings but several peaks in other months were also recorded (Fig. 8) and this may be due to variation of different sites. He recorded gravid female of S. zygaena in February, March, May and October. Information on berried female of this species is absent in this study, however, Fig. 9 shows peak abundance in January, March and July while moderate catch in August, October onwards and this may be indirectly related to new recruitment. The differences in appearance or assemblage of a species can be attributed to a number of factors such as territorial habitat, reproduction, change in weather parameters, seasonal migrations and availability of food and different methods of sampling.

V. Conclusions

In the present study, a brief image on the status of shark fishery in Bangladesh has been represented. On the basis of major findings some limitations and necessary measures are detailed as below:

Key features (such as nostrils, gill slits, mouth position, various lengths, body coloration etc.) used to make distinctions between different species of sharks and rays are so close that it often makes confusion. Therefore, detail species profile needs to be developed with local names, valid scientific names, pictures and status in IUCN red list. Further, for easy and correct identification at field level, guide book and training on taxonomy need to be provided for the data collectors. In absence of long term data record (both species and area wise), it becomes difficult to make absolute comment on changes in species composition over time and area, landing pattern, abundance, size distribution and vulnerability of a species. Existing data recording system is not so consistent and accessible to all stakeholders. At present, detail catch data on shark and ray fishes is maintained from MFSMU, Chittagong which should be extended to the south western coastal districts as well. In this regard, the capacity of MFSMU, Chittagong needs to be strengthened. Information on biological aspects, population parameters (e.g. growth rate, mortality, exploitation rate, recruitment pattern, maximum sustainable yield, biomass etc.), fishing effort (e.g. fish days, gear, mesh size, fishing depth etc.) and impacts of environmental changes on shark fishery are still very limited to interpret catch data. Therefore, accumulation of data and information together with need based research is of prior importance. Shark fishery although has a minor contribution to the total catch, its potential to the economy and biodiversity of our country is noteworthy. Therefore, a National Plan of Action (NPOA) for sustainable management and development of the fishery is an urgent need.

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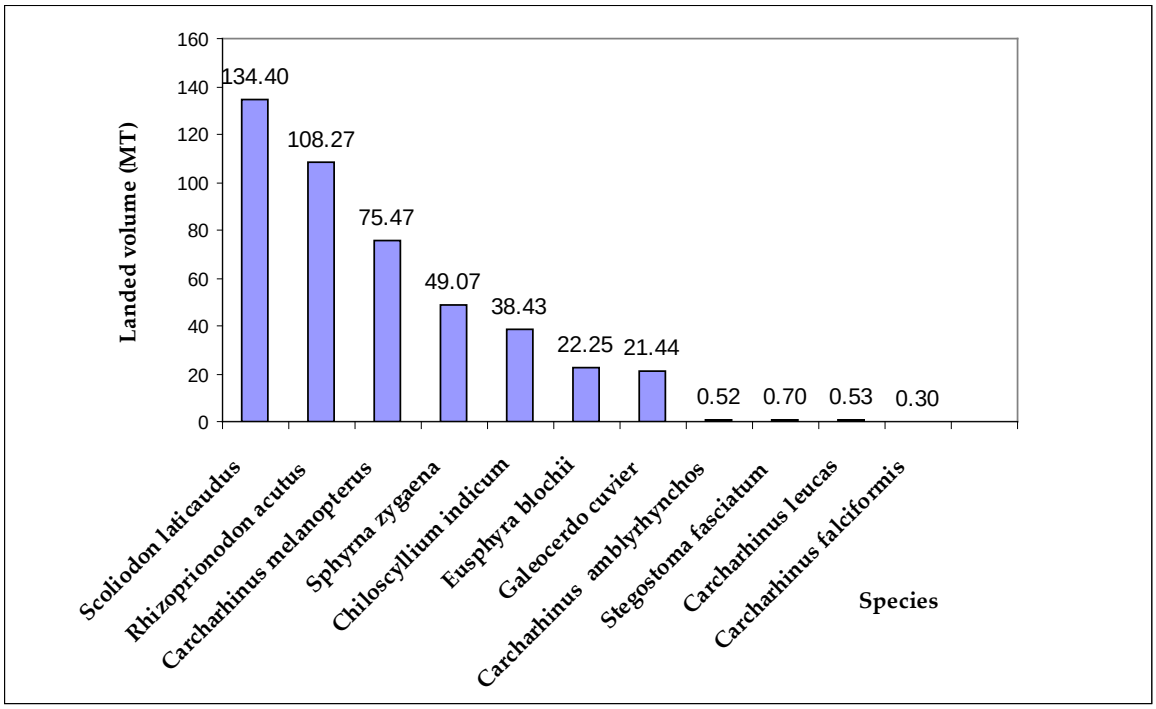

Figure 1 : Total landing of Shark species in Chittagong and Cox's Bazar from April 2006 to June 2010

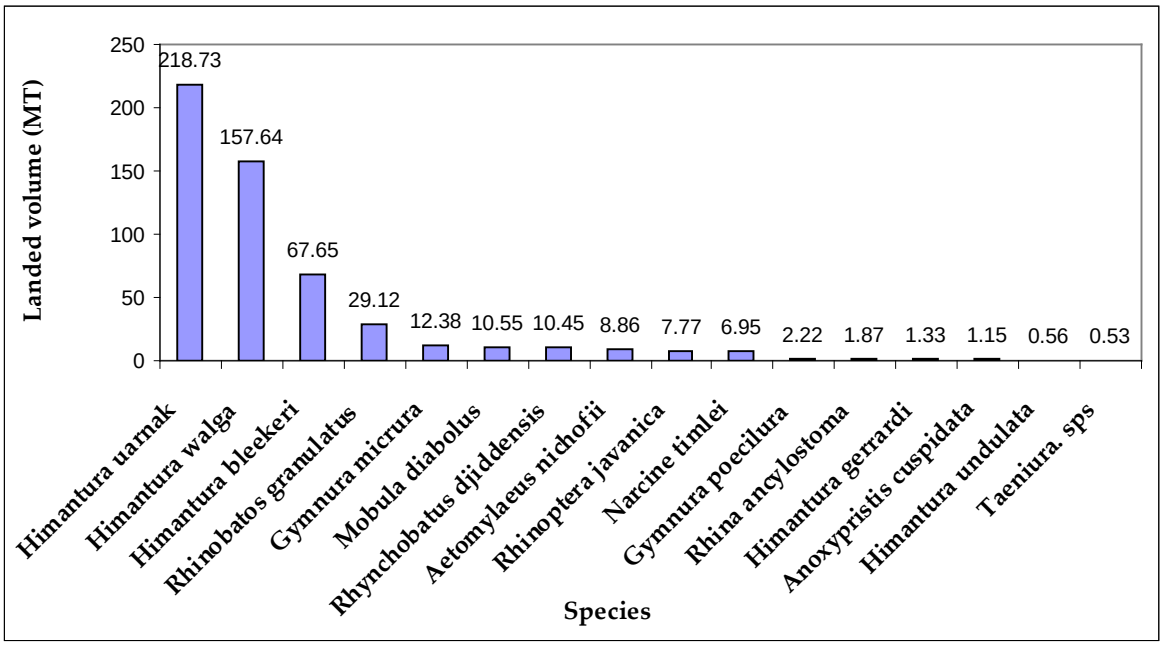

Figure 2 : Total landing of Ray Species in Chittagong and Cox's Bazar from April 2006 to June 2010

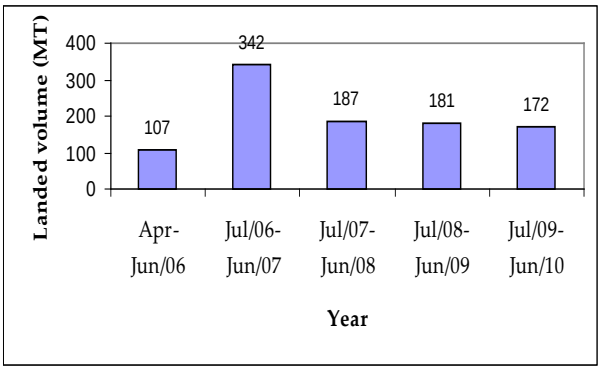

Figure 3 : Total landing of Shark and Ray in Chittagong and Cox's Bazar from April 2006 to June 2010

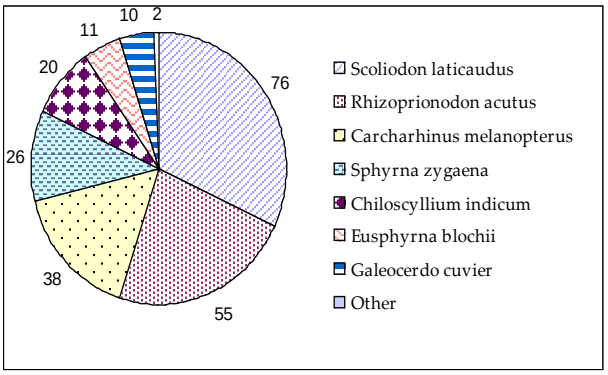

Figure 4 : Percent Contribution of Shark Species in Chittagong and Cox;s Bazar from April 2006 to June 2010

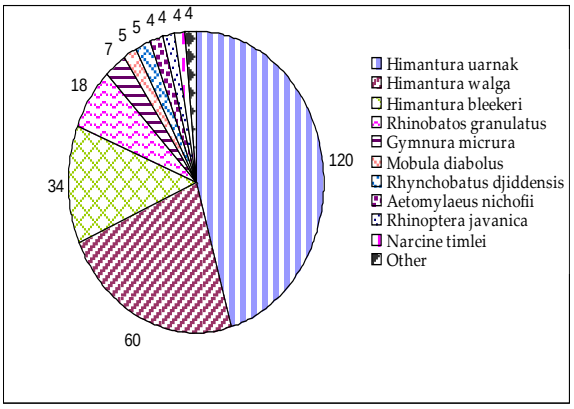

Figure 5 : Percent Contribution of Ray Species in Chittagong and Cox;s Bazar from April 2006 to June 2010

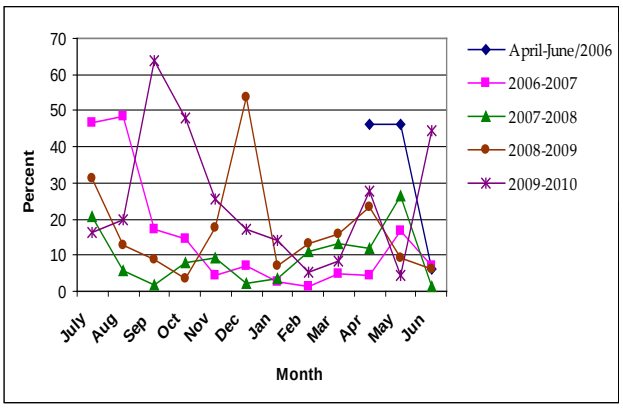

Figure 6 : Percent Contribution of Scoliodon laticaudus in Chittagong and Cox's Bazar from April 2006 to June 2010

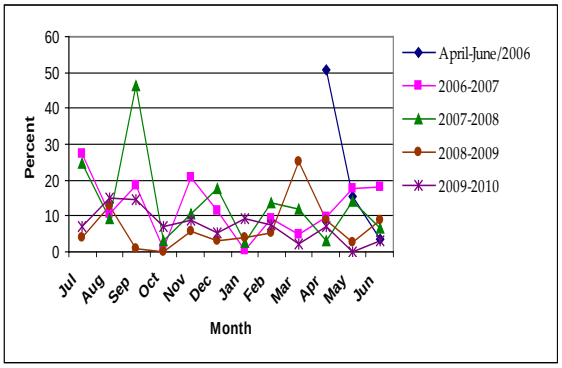

Figure 7 : Percent Contribution of Rhizoprionodon Acutus in Chittagong and Cox's Bazar from April 2006 to June 2010

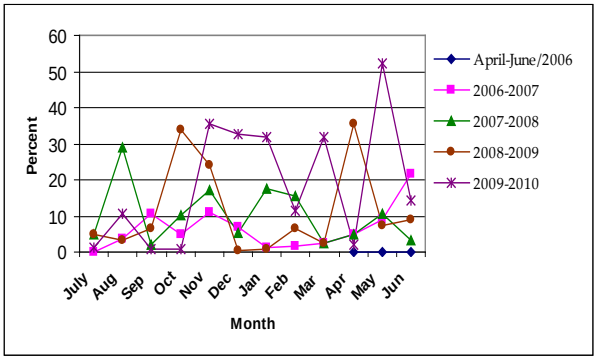

Figure 8 : Percent Contribution of Carcharhinus melanopterus in Chittagong and Cox's Bazar from April 2006 to June 2010

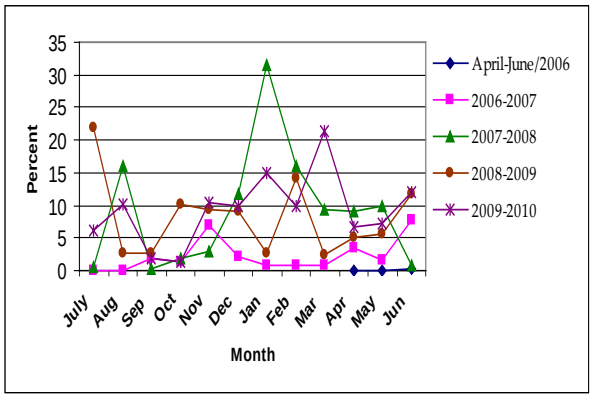

Figure 9 : Percent Contribution of Sphyrna Zygaena in Chittagong and Cox's Bazar from April 2006 to June 2010

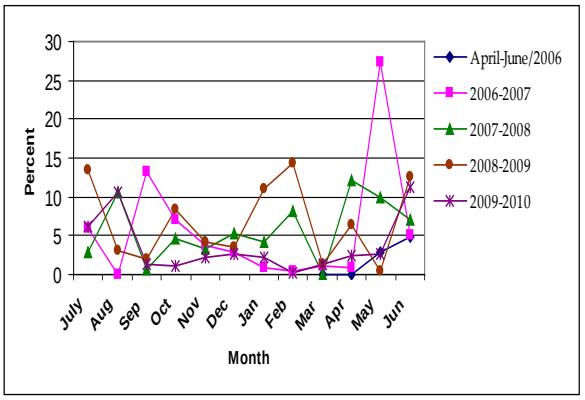

Figure 10 : Percent Contribution of Chiloscyllium indicum in Chittagong and Cox's Bazar from April 2006 to June 2010

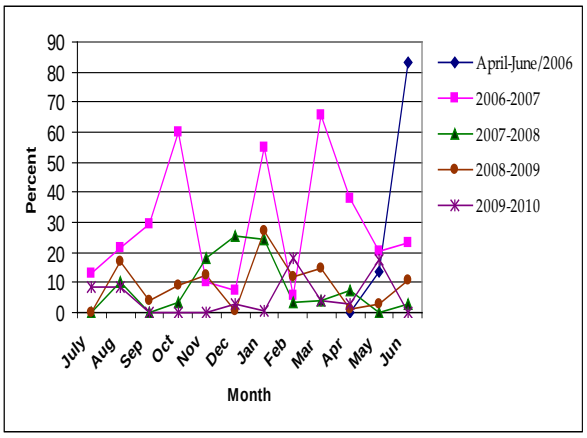

Figure 11 : Percent Contribution of Himantura uarnak in Chittagong and Cox's Bazar from April 2006 to June 2010

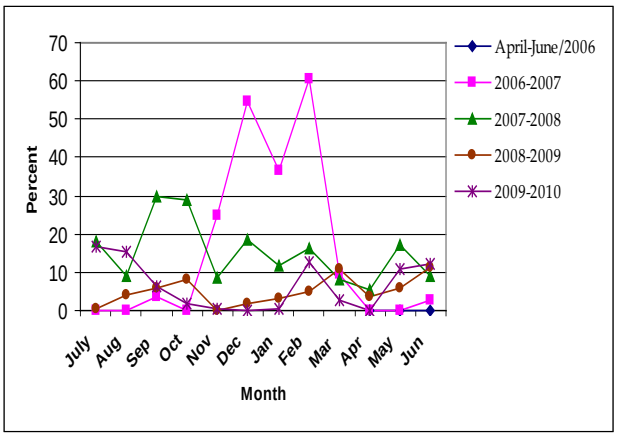

Figure 12 : Percent Contribution of Himantura walga in Chittagong and Cox's Bazar from April 2006 to June 2010

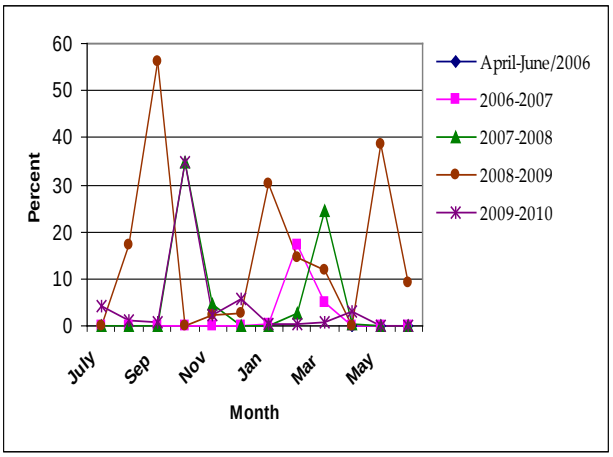

Figure 13 : Percent Contribution of Himantura bleekeri in Chittagong and Cox's Bazar from April 2006 to June 2010

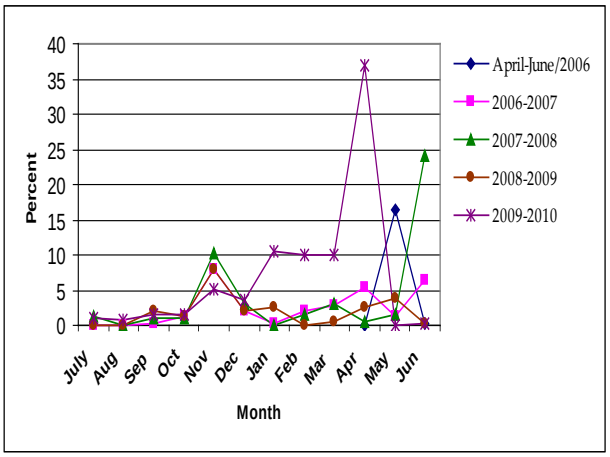

Figure 14 : Percent Contribution of Rhinobatos granulatus in Chittagong and Cox's Bazar from April 2006 to June 2010

Table 1 : Total landing and Percent Contribution of Sharks and Rays in Chittagong and Cox's Bazar District from April 2006 to June 2010

Sl.	Species name	English name	April/2006 - June/2006		July/2006- June/2007		July/2007 -June/2008		July/2008- June/2009		July/2009 -June/2010		Total Landing(MT)
A.	SHARKS		Landing (MT)	% Contribution	Landing (MT)	% contribution	Landing (MT)	% contribution	Landing (MT)	% contribution	Landing (MT)	% contribution	
1.	*Scoliodon laticaudus*	Yellow dog shark	16.835	15.71	22.037	6.45	18.340	9.77	33.271	18.39	43.914	25.49	134.397
2.	*Rhizoprionodon acutus*	Sharp nosed shark (milk shark)	9.030	8.42	30.992	9.07	42.294	22.52	13.340	7.37	12.614	7.32	108.27
3.	*Carcharhinus melanopterus*	Black shark			16.209	4.74	14.094	7.51	12.646	6.99	32.525	18.88	75.474
4.	*Sphyrna zygaena*	Round headed hammer head shark	0.275	0.26	6.612	1.94	13.086	6.97	11.854	6.55	17.242	10.01	49.069
5.	*Chiloscyllium indicum*	Ridge back cat shark	4.597	4.29	11.874	3.48	7.157	3.81	9.892	5.47	4.911	2.85	38.431
6.	*Eusphyrna blochii*	Arrow headed hammer head shark	0.449	0.42	4.636	1.36	8.202	4.37	6.114	3.38	2.852	1.66	22.253
7.	*Galeocerdo cuvier*	Tiger shark	0.170	0.16	7.007	2.05	5.081	2.71	4.091	2.26	5.093	2.96	21.442
8.	*Carcharhinus amblyrhynchos*	Grey shark					0.708	0.38			0.515	0.30	1.223
9.	*Stegostoma fasciatum*	Zebra shark	0.206	0.19	0.050	0.01	0.392	0.21	0.050	0.03	0.003	0.001	0.701
10.	*Carcharhinus leucas*	Bull shark									0.527	0.31	0.527
11.	*Carcharhinus falciformis*	Silky shark					0.304	0.16					0.304
B.	**RAYS**												
12.	*Himantura uarnak*	Honeycomb whip ray	70.950	66.20	106.873	31.28	14.535	7.74	18.638	10.30	7.737	4.49	218.733
13.	*Himantura walga*	Scaly sting ray			103.042	30.16	35.643	18.98	9.566	5.028	9.392	5.45	157.643
14.	*Himantura bleekeri*	Whiptail sting ray			15.139	4.43	8.657	4.61	35.452	19.60	8.400	4.88	67.648
15.	*Rhinobatos granulatus*	Granulated shovel nose ray	3.330	3.11	8.198	2.40	1.372	2.99	3.786	2.09	12.431	7.22	29.117
16.	*Gymnura micrura*	Short tail butterfly ray	0.270	0.25	0.154	0.05	0.830	0.44	4.508	2.49	6.620	3.84	12.382
17.	*Mobula diabolus*	Leaser Devil ray (Bat ray)	0.165	0.15	2.001	0.59	2.415	1.29	4.977	2.75	0.993	0.58	10.551
18.	*Rhynchobatus djiddensis*	White spotted shovel nose ray	0.375	0.35	2.394	0.70	5.616	3.00	1.803	1.00	0.260	0.15	10.448
19.	*Aetomylaeus nichofii*	Nieuhof's eagle ray			1.335	0.39	6.608	3.53	0.855	0.47	0.066	0.04	8.864
20.	*Rhinoptera javanica*	Javanese cow ray			0.933	0.27	0.154	0.08	2.850	1.58	3.832	2.22	7.769
21.	*Narcine timlei*	Spotted electric ray			1.815	0.53	0.494	0.47	4.044	2.24	0.597	0.35	6.95
22.	*Gymnura poecilura*	Long tail butterfly ray						0.08	1.845	1.02	0.374	0.22	2.219
23.	*Rhina ancylostoma*	Bow mouthed guitar fish (shark ray)	0.530	0.49	0.175	0.05	0.928	0.26			0.240	0.14	1.873
24.	*Himantura gerrardi*	White spotted whip ray							1.333	0.74			1.333
25.	*Anoxypristis cuspidata*	Knife tooth saw fish			0.220	0.06	0.883				0.042	0.02	1.145
26.	*Himantura undulata*	Leopard whip ray									0.560	0.33	0.560
27.	*Taeniura. sps*	Fantail ray									0.526	0.31	0.526
	Total		107.182		341.696		187.793		180.915		172.266		989.852

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Effect of Intercrop Row Arrangement on Maize and Haricot Bean Productivity and the Residual Soil

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Abstract- On farm studies were conducted to determine the effects of intercrop row arrangements on the performances of maize (Zea mays L.) and haricot bean (Phaseolus vulgaris L.) crops and the residual soil at Hallabaand Tabaareas, southern Ethiopia. The result revealed that there were significant differences among the cropping patterns on growth and yield components of both crops. Grain yield of the maize crop was observed to be the highest insole stand, which was statistically at par with the maize grown in 1:1 ratio with haricot bean. There was 15.5% yield reduction in maize when the number of haricot bean rows introduced between two maize rows increased from one to three, attributable to aggravation of inter-specific competition in the latter case. In the case of haricot bean crop, compared to the sole stand intercropping of one, two and three rows of haricot bean between two rows of maize had resulted in yield reductions of 56, 44.5 and 28.2%, respectively. Evaluation of the land use efficiency of the system in terms of land equivalent ratio (LER) has, however, showed improvement across the cropping pattern, where by 1:3 maize-haricot bean row ratio gave the highest land use efficiency value, 54% more efficient than growing both crops in sole stand. Total N content of the residual soil has also showed significant improvement due to the introduction of the leguminous haricot bean into the cropping system. In contrast, sole maze stands had contributed the least in amending the acidity problem of the experimental soils.

Keywords: *grain yield; lAI; LER; kernel; row ratio; total soil n.*

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I. Introduction

Agriculture in the next decade will have to produce more food from less area of land through more efficient use of natural resources with minimal impact on the environment in order to meet the growing population demands (Hobbs et al., 2008). Multiple cropping offers one of the best ways of increasing production per unit area by growing two crops of dissimilar growth habit in the same field with little intercrop competition. Traditionally, intercropping is being used by small farmers to increase the density of their products and stability of their output. Cereal-legume mixtures have been adjudged the most productive form of intercropping since the cereals may benefit from the nitrogen fixed in the root nodules of the legumes in the current cropping year (Chalk, 1996; Adu-Gyamfiet al., 2007; Undieet al., 2012) or in the subsequent years (Giller and Wilson, 1993). In this regard, there is a possibility of root exudates or the decay of roots and nodules causing the release of N from legumes into the rhizosphere during the cropping season (Vandermeer, 1989). Legumes in intercropping could also provide N benefits to subsequent crops from the mineralization of N from their residues or from the N sparing effect, where a legume crop can fix atmospheric N_2, thereby reducing competition for soil NO_3^- with a nonlegume crop (Vandermeer, 1989; Anil et al., 1998).

The extent of competition-induced yield loss in intercropping is likely to depend on the spatial arrangement of the component crops. Spatial arrangement of intercrops is an important management practice that can improve radiation interception through more complete ground cover (Heitholtet al., 2005). Choice of appropriate population density, therefore, seems relevant management options in improving the efficiency of this system. Therefore, there is potential for higher productivity of intercrops when intra-specific competition is less than inter-specific competition for a limiting resources (Banik and Sharma, 2009). Arrangement of crops in mixture in the traditional farming systems of Hallaba and Taba areas, Southern Ethiopia is random and without any sufficient attempt to pattern the crops for effective interception of essential resources. Much of the poor crop yields obtained in traditional crop production systems of these areas might be attributable in part to improper crop arrangement with its attendant waste of essential environmental resources.

A wide range of legume-maize intercrops have been found to respond better to two rows of legume after one row of maize (Odhiambo and Ariga, 2001; Mareret al., 2007; Banik and Sharma, 2009). Since crop arrangement is a function of plant density, there is therefore, higher light interception at wider spacing than at narrower spacing (Keating and Carberry, 1993; Prasad and Brook, 2005; Jiao et al., 2008).The performance of an additive or superimposed population of haricot bean in maize as intercrop has not been investigated in this Hallaba and Tabaareas. In view of the above reasons, this research was undertaken with the objective to determine the effects of intercrop row arrangements of haricot bean and maize crops in

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additive model on productivity and residual soil at Hallabaand Tabaareas of southern Ethiopia.

II. Materials and Methods

a) Description of the Study Areas

On farm studies were carried out in the cropping seasons of 2013 at Hallaba and Taba areas, southern Ethiopia, to determine of effects of intercropping maize with haricot bean crop at different population densities on the productivity of component crops. In the 2013 cropping season Hallaba and Taba, received annual rainfall of 970 and 1326 mm, respectively. The annual mean maximum temperatures of the two areas were 26.3 and 24.0^{0}C while the mean minimum temperatures are 14.2 and 11.5^{0}C, respectively (Fig. 1). The soil of the study areas are clay loam in texture, acidic in reaction, low in organic matter, N and other essential nutrients (Table 1).

b) Experimental Treatments and Data Collection

In this study 333,333 plants ha^{-1}obtained from a 20cm by 15cm inter and intra-row spacing, respectively, was considered as optimum plant population for sole crop and the three different proportions of haricot bean: 25% (83,333 plants ha^{-1}), 50% (166,666 plants ha^{-1}) and 75% (249,999 plants ha^{-1}) was interplanted with constant maize population (50,000 plants ha^{-1}) in an additive model, which resulted into three maize: haricot bean row arrangements: 1:1, 1:2 and 1:3. A constant 80cm by 25cm inter and intra-row spacing, respectively, was maintained for maize in both cropping systems (sole and intercrop); because any variation in intercropped maize compared with sole cropping would be attributed to the addition of beans between maize rows.. Experimental plots were 19.6m^2 (3.5m x5.6m) size each. The experiment was arranged in a randomized complete block design with three replicates. Planting materials of maize and haricot bean used in this study were BH-540 and Hawasa-Dume varieties, respectively.

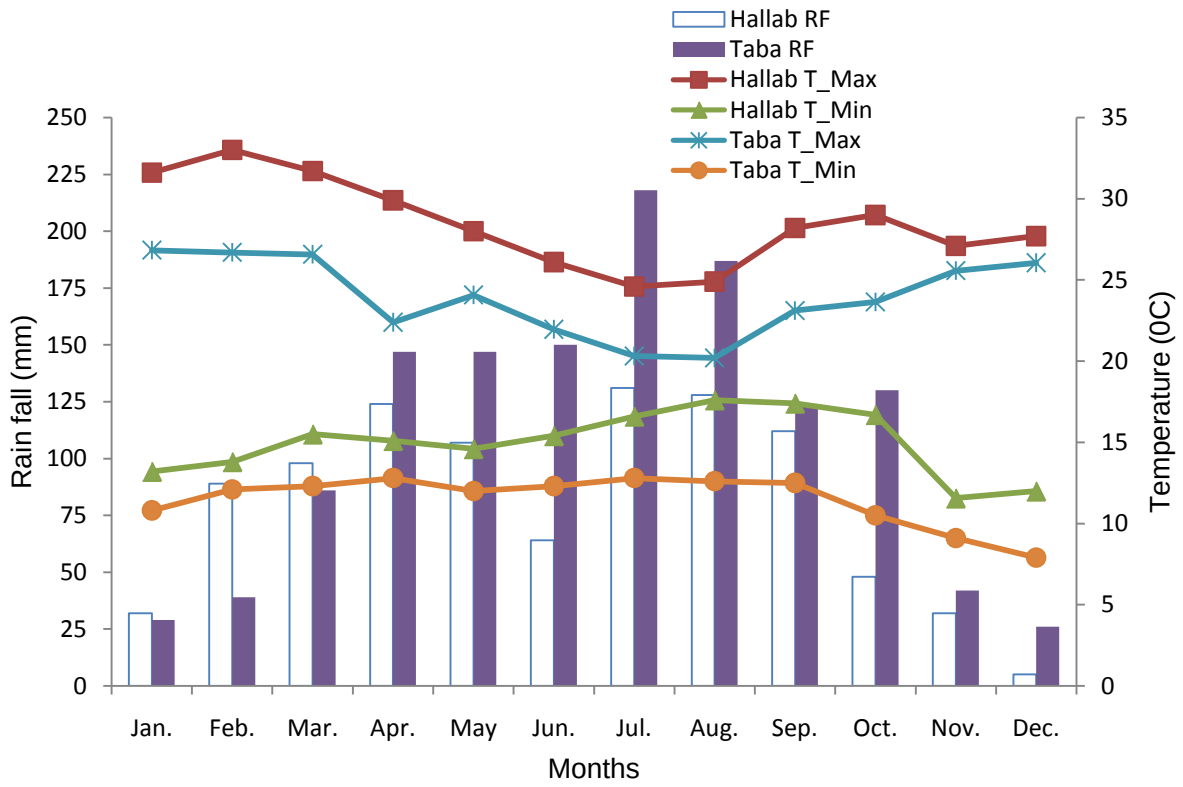

Fig. 1 : Monthly Mean Minimum and Maximum Temperature (^{0}C) and Rain Fall (Mm) Data of Hallaba and Taba Areas

RF = Rain fall; T = Temperature.

Table 1 : Selected Characteristics of the Initial Topsoil (0-20 Cm) at the Two Trial Sites

Soil parameters	Hallaba site	Taba site
pH H_2O (1:2.5)	5.83	5.85
Organic C (%)	0.63	0.65
Total N (%)	0.22	0.22
Aval. P (mg/kg soil)	29.33	48
Exch. K (cmol (+) /kg soil)	0.64	0.56
CEC (cmol(+)/kg soil)	20.93	17.2
EC (ds/m)	0.18	0.16
Clay (%)	33	30
Silt (%)	37	36
Sand (%)	30	34

To determine the response of maize haricot bean crops to intercropping, data were collected on some selected growth, yield and yield related parameters. The production efficiency of intercropping system vis-à-vis the respective monocultures was computed using competition indices like land equivalent ratio (LER), land equivalent coefficient (LEC) competitive ratio (CR). LER was calculated by summing the relative intercrop yield of the components (maize yield in mixture/maize yield in sole) + (haricot bean yield in mixture/haricot bean yield in sole).Whereas the formula used for computing the LEC is: $LER_{maize} \times LER_{haricot\ bean.}$ The formula used to calculate CR was the ratio of the partial LERs of the components multiplied by the inverse ratio of their sown proportion. To determine the effect of N-fixing haricot bean on soil, sampling of soil was done twice; at pre-planting and right after harvesting. Soil samples were air dried, crashed, sieved to prepare for the analysis of chemical properties like soil pH, total organic C content, total N, available P, exchangeable K and the CEC of the soil using the standard laboratory procedures.

The crop (agronomic) and soil data collected at the two sites during the course of the study were subjected to analysis of variance using SAS. Least significant difference (LSD) test at 95% confidence interval was used to separate treatment means when ever significant effects were observed on parameters. Since the error variable was homogenous, instead of site wise data, pooled values were given for discussion and interpretation.

III. Results and Discussion

a) Effect on Maize Crop

In the present study, combined analysis of data over location showed that height of maize was non-significantly affected by cropping system. However, significant differences were observed among the treatments with regard to leaf area index (LAI) values, whereby maize in 1:1 row ratio with bean produced the highest value (4.3), even more than the sole stand, while the maize plants in 1:3 row combination gave the least (Table 2) attributable to complementarity between the components at lower population density and aggravated completion from the higher densities.

Table 2 : Effect of Row Proportion of Haricot Bean in Intercrop on Growth of Maize Crop (Pooled Data of 2 Sites)

Maize: Haricot bean row proportion	Growth parameters		
	Plant height (cm)	LAI	Stover yield (t/ha)
Sole maize	2.19	4.1a	10.8a
1:1	2.14	4.3a	9.5ab
1:2	2.09	3.7ab	9.5ab
1:3	2.01	3.1b	8.3b
LSD(0.05)	NS	0.82	2.29

Values within a column followed by the same letter are not significantly different at 5% probability level.

The effect of the spatial arrangement of haricot bean intercropped with fixed population of maize was also found significantly affecting the stover yield of the main crop (maize), whereby maize in the sole stand produced the highest stover yield (10.8 t/ha). According to this data, raising the population of bean plant from 1:2 to 1:3 reduced the biomass production of maize by about 12.6% (Table 2).

Number of cobs produced on per m^2 basis was observed to be unaffected by the adopted cropping system. On the other hand, cob length was found to be significantly affected by intercrop row ratio of haricot bean, in which the largest cobs being produced under sole stand of maize crop, which is at par with that of maize in 1:1 row ratio with haricot bean (Table 3). In this regard the smallest cobs were recorded in plots where the highest number of haricot bean rows were introduced between the two maize rows (1:3). Similar to cob length the number of kernels per row of maize cobs was observed to be significantly affected by the adopted cropping system, whereby maize grown in 1:1 row combination with bean produced cobs with the highest kernels per row, while 1:3 row ratio producing the least (Table 3).

Table 3 : Effect of Row Proportion of Haricot Bean in Intercrop on Yield Related Parameters of Maize Crop (Pooled Data of 2 Sites)

Maize:Haricot bean row proportion	Yield related parameters		
	Cobs/m²	Cob length (cm)	No. kernels/row
Sole maize	3.8	16.06a	34.0a
1:1	3.6	15.66ab	34.6a
1:2	3.4	14.38bc	30.6b
1:3	3.4	13.66c	29.5b
LSD(0.05)	NS	1.30	2.96

Values within a column followed by the same letter are not significantly different at 5% probability level.

Grain production on per plant basis was found to be affected by the cropping system where maize in 1:1 row combination produced the highest (131 g), 32.7% more grain yield per plant than that of 1:3 row ratio (Table 4). The results therefore suggest that a bean spatial arrangement of one bean row in between maize rows was less competitive to maize in the intercrop. Similarly Silwana and Lucas (2002) and Morgado and Willey (2008) reported decreased grain yield per maize plant by more than 30% compared to sole cropping. While considering the total grain yield on per hectare basis the maize crop grown in 1:1 ratio with haricot bean was the highest yielding among the intercropped plots, and it's also statistically at par with the highest of all, sole crop (Table 4). As haricot bean population increases total grain yield of maize keeps on decreasing, showing 12.8% yield reduction as the proportion of haricot bean population increased from 25 to 75% of its pure stand in constant maize population (1:1 to 1:3 maize: haricot bean row ratio). Maize yield difference of 0.54 t/ha between 1:1 and 1:3 row combinations with haricot bean is attributable to magnified completion in the latter case. In corroboration to present finding, Zama and Malik (2000) and Mutungamiriet al. (2001) have reported lower grain yield records from plots where maize was intercropped with two and three rows, respectively, of bean compared to 1:1 row arrangement. Harvest index (HI) and 100-kernel weight of the maize crop were, however, found unaffected by the row arrangement adopted for this study. Similarly Undies et al. (2012) have reported that intercropping and crop arrangement had no significant effect on 100-grain weight.

Table 4 : Effect of Row Proportion of Haricot Bean in Intercrop on Productivity of Maize Crop (Pooled Data of 2 Sites)

Maize:Haricot bean row proportion	Grain yield per plant (g)	Total grain yield (t/ha)	HI	100-kernel weight (g)
Sole maize	116.7b	3.68a	0.27	26.76
1:1	131.4a	3.49ab	0.26	28.25
1:2	104.5bc	3.00b	0.25	26.73
1:3	99.11c	2.95b	0.23	26.55
LSD(0.05)	16.01	0.56	NS	NS

Values within a column followed by the same letter are not significantly different at 5% probability level.

b) Effect on Haricot Bean Crop

Table5 shows that there was significant effect of intercrop row ratio observed with respect to the height of haricot bean plants. In this regard the tallest and shortest plants were recorded from the 1:2 maize-bean row combination and the sole stand, respectively. Among the intercrop combinations, however, plots with the highest bean population recorded the least height of the bean plants, attributable to aggravations of both intra- and inter-specific completion for growth resources. Similarly, Undies et al. (2012) reported that soybean plant height increased above its sole crop at different intercrop row arrangements. In contrast to the present finding, Zama and Malik (2000) have reported that height of ricebean plants in intercropping with maize significantly reduced as compared to plants in the sole crop.

The branching pattern and dry matter production of the haricot bean crop were also observed to be significantly affected by sown proportion of the intercrops (Table 5); in which the highest mean branching and dry weight values were observed in one-to-one ratio, the least values being recorded from one-to-three row ratio (Table 5). Presumably lower inter and intra-specific competition due to the lower population density at 1:1 row ratio might have provided a better soil resource condition with higher light availability for bean plants to grow vigorously. Similar to present finding, Morgado and Willey (2003) also found that dry matter per plant of beans decreased significantly as bean population increased in intercrop with maize.

Table 5 : Effect of Sownproportion on Growthof Haricot Bean Intercropped with Maize (Pooled Data of 2 Sites)

Maize:Haricot bean row proportion	Growth parameters				
	Plant height (cm)	No. of branches	Dry weight (g)	Total no. of nodules	No. of effective nodules
Sole haricot bean	31.48b	2.0ab	20.4b	6.1ab	1.3ab
1:1	44.90a	2.4a	30.4a	11.8a	2.1a
1:2	45.98a	1.9b	21.2b	5.8ab	1.0ab
1:3	40.85a	1.6b	19.9b	4.6b	0.3b
LSD(0.05)	7.46	0.43	8.09	6.41	1.34

Values within a column followed by the same letter are not significantly different at 5% probability level.

Nodulation pattern, being the prerequisite for symbiotic N^2 fixation, showed a highly significant difference among the intercropping patterns where haricot bean plants in 1:1 row ratio produced the highest mean number (11.8 plant^{-1}) as averaged across the locations (Table 5). According to Mandalet al. (2014) nodule formation in soybean had been observed to be unaffected due to intercropping with maize. Similar to total count the number of effective nodules, nodules which developed pink-red color when slice opened, were highest at 1:1 ratio. Intercropping effects on nitrogen fixing attributes of haricot bean were influenced by population density. Symbiotic N_2 fixation is highly dependent upon the flow of photo-assimilates to nodules (Paul and Kucey, 1981; Akundu, 2001). This relation is also coupled to yield. Thus any factors that influence photosynthesis will concomitantly influence nitrogen fixing attributes. Plant density influenced canopy development. Intercropped haricot bean provided a heavy shading as though they were a cover crop. Light penetration in such heavy shading was minimal. This in turn influenced photosynthetic process. Such response may have been responsible for the observed decreases in number of total and effective nodules at 1:3 row ratio, 24.6% and 76% respectively, compared to the sole stand.

In this study numbers of pods/plant and seeds/pod were found statistically identical (Table 6). Nudunguet al. (2005) similarly reported non-significant ($P<0.05$) influence of special arrangement on grain accumulation in each pod. On the other hand, hundred seed weight of the haricot bean grown in differential mix proportion at the two sites was observed to be significantly affected, where byall the intercrop treatments produced higher (and statistically identical) 100-grain weight than the sole stand (Table 6). In difference with present finding Zama and Malik (2000)and Undieset al. (2012) have observed significantly lower test weight of the seeds of the legume components in intercrop than the sole stand.

Total grain yield of the haricot bean crop was observed to be affected by varying mix ratio. In this regard the highest yield was recorded from the sole haricot bean plot, and grain yield declined with the proportion of haricot bean rows in the mixture (Table 6). This is attributable to proportion of the land occupied by bean crop in the intercrop as yield is linearly related to plant population. Intercropping of one, two and three rows of haricot bean between maize rows in the present study resulted in 56, 44.5 and 28.2% reduction of haricot bean yield, respectively compared with haricot bean in sole stand. Undies et al. (2012) in the same way reported a significantly lower grain yield of soybean under intercropping with sorghum as compared with the pure stand.

Table 6 : Effect of Rowproportion on Yield Components of Haricot Bean Intercropped with Maize (Pooled Data of 2 Sites)

Maize:Haricot bean row proportion	Yield and yield components			
	Pods/plant	Seeds/pod	100 seed weight (g)	Grain yield (t/ha)
Sole haricot bean	13.3	4.6	27.4b	3.73a
1:1	15.0	4.2	29.7a	1.64c
1:2	14.5	4.7	29.6a	2.07bc
1:3	14.1	4.4	29.9a	2.68b
LSD(0.05)	NS	NS	1.92	0.67

Values within a column followed by the same letter are not significantly different at 5% probability level.

NS = Non-significant.

Generally, the yield of haricot bean in pure stand maintained supremacy over the intercropping system due to the obvious reason of lower proportion of sown area. This may also be due to limited disturbance of the habitat and interactional competition under sole cropping environment (Banik, 1996). On the other hand, when maize was grown with the association of haricot bean, irrespective of different combinations, the maize

crop benefitted in respect of the proportionate yield of sole crop. This can be attributed to the complementary effect of legume association (Adhikaryet al., 1991; Banik and Bagchi, 1993; Banik, 1996).

c) Intercrop Efficiency

As an indication of land use efficiency partial land equivalent ratio of haricot bean (LER_h) was significantly affected by the row proportion of haricot bean in the mixture but that of maize (Table 7). Accordingly, a 1:3 maize-to-haricot bean row ratio gave the highest value (0.73), while 1:1 row mix being the lowest in its partial land equivalent ratio (Table7). Evaluation of the overall land use efficiency (LER_t = LER_m + LER_h) in the present study showed a significantvariation among the treatments of cropping pattern (Table 7). The data revealed that intercropping of maize with haricot bean in 1:3 ratio gave the highest land use efficiency value, 54% more efficient than growing both crops in sole stand.

Table 7 : Efficiency of Intercropping Maize and Haricot Bean Crops as Affected by Row Proportion (Pooled Data of 2 Sites)

Maize:Haricot bean row ratio	Intercrop efficiency					
	LER			CR		LEC
	LER_h	LER_m	LER_t	CR_h	CR_m	
1:1	0.48b	0.95	1.43ab	0.51a	2.2	0.46b
1:2	0.58ab	0.82	1.40b	0.39ab	3.75	0.43b
1:3	0.73a	0.81	1.54a	0.31b	3.39	0.58a
LSD(0.05)	0.16	NS	0.11	0.18	NS	0.11

Values within a column followed by the same letter are not significantly different at 5% probability level.

CR = Competitive ratio; LEC = Land equivalent coefficient; LER = Land equivalent ratio; NS = Non-significant.

According to Adetiloyeet al. (1983), for a two-crop mixture the minimum expected productivity coefficient is 25%; meaning a yield advantage is obtained if land equivalent coefficient (LEC) value exceeds 0.25. In this regard all maize: haricot bean intercrop combinations in this study had LEC values above 0.25, suggesting yield advantages. Though, all maize haricot bean mixes exhibited LEC values greater than the critical, the highest population density (1:3) recorded the largest (0.58) of all mixes (Table 7). Egbe (2010) has similarly reported LEC values greater than the critical in intercropping sorghum with soybean at different spatial arrangements. The data of competition ratio (CR) indicate that maize is the dominant crop in this mixture though non-significantly affected by the cropping pattern. Even though haricot bean crop was found to be dominated by the vigorous maize, change were observed in competitive behavior of haricot bean across the intercropping pattern. In this aspect adding 25% of the pure haricot bean stand in in maize (1:1 row ratio) was observed to exhibit the highest competitive value, attributable to minimized intra and interspecific competitions at lower population density (Fisher et al., 1986).

d) Effect on Residual Soil

Laboratory analysis of soil samples collected both at pre-planting and post-harvest indicate that all soils are in slightly acid range, but the acidity has significantly decreased by all of the adopted cropping system from the initial (pH = 5.83). Pure maze plots had the lowest soil pH (6.20) compared to plots intercropped with haricot bean and the sole haricot bean stand (Table 8), implying that bean in intercropping and sole have better potential in ameliorating soil acidity than sole maize. Concomitant to present finding, Ossom and Rhykerd (2007) have reported that sole field bean had superiority in raising the soil pH over pure maze. Ariel et al. (2013) however, have reported that pH values of the rhizosphere soil remained fairly constant during the cropping cycles of intercropping maize with soybean.

Although the organic C content of the soilremained statistically unchanged during the cropping cycle, plots under intercropping tended to showed increasedorganic C content, while the pure stands of both crops recorded a reduction compared to the initial (Table 8).Similar observation was also made by Ossom and Rhykerd (2007).Total N content of the soil before and after the experiment revealed that there is significant improvement in N status due to the introduction of the leguminous species (Phaseolus vulgaris) into the cropping system. In this respect growing the haricot bean crop as a sole stand enhanced the N in the soil by about 27.3%; whereas 1:1 maize-haricot bean row combination improved the total N of the soil by about 18.2% from the initial (Table 8). Likewise, Szumigalski and Van Acker (2008) also reported a higher residual N content of the soil in plots allocated to sole pea than the intercropped with wheat. The improvement of soil N in plots where haricot bean was grown both as a sole and intercrop in the present study could be due to a possibility of root exudates or the decay of roots and nodules causing the release of N from the legume components into the rhizosphere during the cropping season (Vandermeer, 1989, Szumigalski and Van Acker, 2008).

Table 8 : Effects of Intercropping System of Maize with Haricot Bean on Some Selected Soil Chemical Properties (Pooled Data of 2 Sites)

Cropping system (maize:haricot bean row ratio)	pH H_2O (1:2.5)	Organic C (%)	Total N (%)	Aval. P (mg/kg soil)	Exch. K (cmol(+)/kgsoil)	CEC (cmol(+)/kgsoil)
Initial soil	5.84b	0.64	0.22bc	35.16a	0.60	19.06
Sole maize	6.20ab	0.59	0.25ab	29.33a	0.65	17.87
Sole haricot bean	6.57a	0.59	0.28a	22.00ab	0.72	18.13
1:1	6.57a	0.81	0.26ab	18.00b	0.71	19.07
1:2	6.50a	0.67	0.24abc	17.33b	0.72	18.07
1:3	6.43a	0.76	0.20c	18.67b	0.59	18.73
LSD (0.05)	0.57	NS	0.04	8.90	NS	NS

Values within a column followed by the same letter are not significantly different at 5% probability level.

With regard to the effect on the available P in the soil, significant treatment effect was observed in the present study, whereby plots of all intercrop combinations recorded reduction and statistically identical concentration of av. P in the soil as compared to the initial and pure maize plots (Table 8), attributable to inter-specific competition for the essential resource. Mandalet al. (2014) correspondingly showed that av. P content was reduced in post-harvest soils of all plots in which maize was intercropped with soybean and groundnut at varying row proportion compared to the initial and sole maize. The exchangeable K content and the CEC of the soils were non-significantly affected by the adopted cropping patterns (Table 8). Ossom and Rhykerd (2007) also reported the non-significant of intercropping maize with field bean.

IV. Conclusions

According to the data of the present study, significant differences among treatments of row combination were observed in some selected growth and yield attributes of maize and haricot bean crops. The grain yields of maize and haricot bean were highest in the respective pure stands, attributable to the absence of inter-specific competition and stand count per unit area, respectively. Looking at the overall land use efficiency, however, all of plots under intercropping recorded LER values greater than a unit, where maize + 75% pure stand haricot bean (1:3 row ratio) being the most efficient one, 54% more efficient than growing both crops in sole stand. Post-harvest soil condition of current experiments revealed that legume intercropping with maize could be better option not only for higher yield to sustain soil fertility as well. Moreover, it has been observed that haricot bean crop, either in intercrop or pure stand, have great role to ameliorate the acidity problems of soils of the study areas. The ultimate consideration for selection of best intercropping system is the advantages and production efficiency. Thus, on the basis of the results of this experiment, maize + haricot bean in 1:3 row additive series intercropping system may be recommended for the Halaba and Taba areas of southern Ethiopia.

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Public Private Partnership Models for Women Entrepreneurship Development in Agriculture

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Abstract- The paper contributes empirical evidence on the status of Public- Private Partnership models (PPP) for rural women entrepreneurship development through Self Help Groups (SHGs) in agriculture and classifies them based on the concept of value creation. The study was conducted in Kerala, India during 2009-12, where women entrepreneurship development in agriculture through SHGs is rampant. Ex-post facto design was used to collect data from a purposive sample of 1400 from the four regionally representative zones of the state. Weighted score and case study methods were used in the selection and classification of the delineated models. Study identified 466 women development projects with PPP components. From this 22 cases with working PPP elements were selected for detailed analysis using a weighted score method. Six models with high scores viz Cadbury-KAU Cooperative Cocoa Research Project, Thirumadhuram Pineapple Project, Uravu RSVY Micro Enterprises Project, Sevashram Organic Producer Company, Subicsha Coconut Producers' Company Ltd and Nendran Banana (Samagra) Project were used for detailed case study. The major public and private agencies involved and focus domains were delineated.

Keywords: value creation, self help groups, women empowerment, social enterprises, public welfare model, private employment model.

GJSFR-D Classification : FOR Code: 970107

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Public Private Partnership Models for Women Entrepreneurship Development in Agriculture

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Abstract- The paper contributes empirical evidence on the status of Public- Private Partnership models (PPP) for rural women entrepreneurship development through Self Help Groups (SHGs) in agriculture and classifies them based on the concept of value creation. The study was conducted in Kerala, India during 2009-12, where women entrepreneurship development in agriculture through SHGs is rampant. Ex-post facto design was used to collect data from a purposive sample of 1400 from the four regionally representative zones of the state. Weighted score and case study methods were used in the selection and classification of the delineated models. Study identified 466 women development projects with PPP components. From this 22 cases with working PPP elements were selected for detailed analysis using a weighted score method. Six models with high scores viz Cadbury-KAU Cooperative Cocoa Research Project, Thirumadhuram Pineapple Project, Uravu RSVY Micro Enterprises Project, Sevashram Organic Producer Company, Subicsha Coconut Producers' Company Ltd and Nendran Banana (Samagra) Project were used for detailed case study. The major public and private agencies involved and focus domains were delineated. Value creation estimated as percentage gains on factors related to income and empowerment for the group members and social and environment gains for the society was used to classify the development models as Public dominated welfare models and Private dominated employment models. Paper establishes the potential of PPP for scaling up entrepreneurship activities in SHGs by convergence of the core assets of public and private sectors. Results also opened possibilities of conceptualization of SHGs as social enterprises and use of PPP strategies in entrepreneurship development.

Keywords: value creation, self help groups, women empowerment, social enterprises, public welfare model, private employment model.

I. Introduction

The search for alternatives to the privatization of public services to improve efficiency saw the emergence of public–private partnership (PPP) as a policy instrument for development in 1980s. It focused primarily on outsourcing public services to private operators in the fields of education, health, and infrastructure, and more comprehensive programs of urban and rural economic development that directly engaged both the public and private sectors (Osborn and Baughn 1990; Gerrad 2001). Literature suggests that PPP is an optimal policy approach to promote social and economic development that brings together the efficiency, flexibility, and competence of the private sector with the accountability, long-term perspective, and social interests of the public sector (Richter 2003; O'Looney 1992; Etzioni 1973). Such partnerships blurred the classic distinction between the public and private sectors in a modern economy. They also enhanced the potential for both efficient and equitable production and distribution of social and economic benefits (Larkin, 1994). Advances in information, institutional and welfare economics also contributed to the evolution of PPP as a development tool (Binenbaum et al. 2001; Williamson 1975, 1991; Rangan et al. 2003).

In India, the post liberalization period after early 1990s saw the emergence of PPP as a unique model for development. However, its use as a policy instrument was mostly limited to infrastructure development, health, education and information technology. It referred to the long term contractual partnership between the public and private sector agencies, specifically targeted towards financing, designing, implementing and operating facilities and services that were traditionally provided by the public sector. The partners entered into specially designed terms and conditions formalized through signed Memorandum of Understanding (MoU) agreeable to both and institutionalised through Special Purpose Vehicle (SPV). Operationally a broader definition for private sector agencies has been accepted under this which includes NGOs from voluntary sector, corporate sector, self help groups, partnership firms, community based organizations and all related agencies. Though such partnerships are found sporadic and uneven in agricultural development, the definition has brought the community based organizations and initiatives at the local level for women empowerment through Self Help groups (SHG) also under the ambit of PPP.

This assumes significance as agriculture is one of the primary economic sectors where the role of women is recognized and pursued for inclusive growth and development in recent years. This is primarily because of the extensive involvement of women in

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agricultural activities with roles ranging from managers to landless labourers. In India 75 percent of all women workers and 85 percent of all rural women workers are engaged in agriculture (Agarwal, 2003). In over all farm production, women's average contribution was estimated at 55% to 66% of the total labour with percentages, much higher in certain regions of the country. The ascending trends of feminization of agriculture has made the issues of gender development and mainstreaming a key strategy not only for the promotion of equality between men and women, but also for sustainable agricultural and rural development. In fact, women Self Help Groups (SHG) constitute one of the core mechanisms devised to reduce the vulnerability of women in agricultural sector. Micro-credit (saving and lending) and community action objectives to ensure women empowerment formed essential strategies of these SHGs (Hashemi et al. 1996). NGOs and public agencies at different levels are involved in building the capacities of these groups with the main focus on group activities and micro credit. Successful efforts have also been made to build their capacity in entrepreneurship activities like apiculture, mushroom production, vermin composting, goat rearing, ornamental fish culture, and floriculture that can improve their socio-economic conditions. Reports indicate that self help programmes have succeeded in changing the lives of poor women by enhancing incomes and generating positive externalities such as increased self-esteem, decision making capacity and access to resources (Swain, 2007). Development strategies that were tried to make agricultural economy better competitive by reducing poverty, enabling food security, ensuring sustainable management of resources and better empowerment of women farmers include PPP, though in minor accounts. It is in this back drop the paper attempts to delineate the status of PPP models for rural women entrepreneurship development in agriculture and classify them based on the concept of value creation.

II. Materials and Methods

The study was conducted in Kerala, the southernmost state of India during 2009-12. Details of present status of Public- Private Partnership models and institutional arrangements for gender mainstreaming of agricultural development initiatives through entrepreneurial ventures were collected. For the purpose of data collection, the State of Kerala has been classified into four zones that included the southern coastal zone comprising of the districts of Thiruvananthapuram, Kollam and Alappuzha and the southern high range zone of Kottayam, Pathanamthitta and Idukki districts. The central zone consisted of Ernakulam, Thrissur, Malappuram and Palakkad and the Wayanaad, Kannur, Kazaragod and Kozhikode districts formed the northern zone. A zone wise compilation of women empowerment programmes implemented in agriculture sector (including crops, dairy, animal husbandry, fisheries, processing and value addition and handicrafts) with the partnerships of development departments, NGOs, Commodity Boards, Banks, Private companies and Multinational corporations with PPP elements was done using a survey instrument developed for the purpose. The purposive sample consisted of 1400 development schemes from the four zones. The collected information was subjected to detailed analysis for identifying types and elements of PPP. This could identify 466 projects in agriculture sector with PPP components from the four zones of Kerala. But many of the identified cases either did not have a working PPP element nor had the partnerships dysfunctional at the operational level over time. Therefore, the detailed study was confined to 22 cases from the four different zones where a definite PPP component was involved either in formal or informal way at the time of study. This was ascertained by quantitative assessment of the PPP elements using a weighted score method involving score card that rated it on functionalities of PPP. The functionalities of PPP studied were initiatives in training and technology support, input supply, value addition and marketing. The weighted score for each model was obtained by multiplying the number of activities taken up with PPP components by the model for women entrepreneurship development to its coverage (Score for coverage of PPP model with jurisdiction at Block Level-1, District Level-2, State Level-3, National Level-4). The 22 selected models were subjected to detailed case study on seven major domains of PPP so as to get comprehensive information on management of PPP chains and its outcome. The selected domains included title and organizations involved, theme area of activity, broad objectives, risk sharing practices, stake of different partners (primary and secondary partners), risk taking mechanisms, resources provided by the partners, sharing of responsibilities, financial proprietary, production and distribution of services/ products, sharing of benefits (as per provision of resources and quantifiable or non-quantifiable benefits shared) and outcome (profit or changes in socio-economic lives of the people involved). The management of PPP chain was evaluated on parameters related to resource management and control, communication, coordination among partners, conflict resolution, transparency of system, feedback mechanism, period of operation and flexibility in planning.

Classification of the models based on value creation estimated on factors related to economic and empowerment gains for the group members and social and environment gains for the society was also attempted. Value creation goes beyond profit and stressed social impact and utility of the activities under taken for the society after accounting for the resources used in the activity, It included the extent to which the

group derives benefits in terms of income, employment, increased customer loyalty and markets. Whereas value appropriation allowed the focal actors involved in the activity to capture and share the value created by the activity. The identified models followed different strategies in balancing these mutually exclusive goals of value creation and appropriation. Separate survey instruments were used for SHG members and community members. Economic gain in terms of percentage improvement in income, employment and other incentives received for the group members that ranged from 1 -100 % was measured quantitatively. Upto 10% improvement was given a score of 1, 11-25% (2), 26-50 % (3), 51-75 % (4) and 75- 100% (5). Women empowerment as part of PPP intervention has been operationalized as a function of six dimensions viz. Social participation, political consciousness, information and resource access, improvement in decision making skills and improvement in cognitive ability and skills. Accordingly empowerment gains were measured in terms of improvement in social participation, political consciousness, information and resource access, decision making and gain in knowledge and skill (Pitt et al. 2006). Perception of the members of the community other than group members with respect to local resource utilization, safe to eat standards of food production, resource recycling and environment conservation practices followed by SHGs rated on a three point continuum of 0, 1 and 2 for negative, neutral and positive responses were used to evaluate value creation for the society.

Table 1 : Weighted Scores of the Selected PPP Models from Kerala, India

Sl. No	Name of the PPP model	District of operation	Zone	PPP Score
1	Cadbury-KAU Cooperative Cocoa Research Project (CCRP)	Thrissur	Central	28
2	Nutrifood	Kasargod	Northern	18
3	Thirumadhuram	Ernakulam	Central	26
4	Kondattom (Samagra)	Palakkad	Central	22
5	Saphalam (Samagra)	Palakkad	Central	20
6	Plant N Plenty (Tissue Culture Unit)	Palakkad	Central	9
7	Samagra Goat Village	Kannur	Northern	18
8	Ornamental fish project	Ernakulam	Central	9
9	Ksheerasagaram (Samagra)	Iddukki	Sothern High range	18
10	Madhuram (Samagra) Honey	Pathanamthitta	Sothern High range	14
11	Subicsha Coconut Producer Company Ltd	Kozhikode	Northern	28
12	Sevasram	Ernakulam	Central	26
13	AVT Plant biotech project	Ernakulam	Central	20
14	M/s.Jaimatha Estates	Kottayam	Sothern High range	18
15	Agri-export zone project	Ernakulam, Thrissur	Central	20
16	Nendran Banana (Samagra)	Trivandrum	Southern Coastal	32
17	Nivedyam (Samagra) Pooja Kadali	Thrissur	Central	24
18	Harithashree (Samagra) project	Malappuram	Central	18
19	Ottappalam Welfare Trust	Palakkad	Central	10
20	Uravu RSVY Micro Enterprises	Wyanad	Northern	28
21	Organic agriculture programme	Alappuzha	Southern Coastal	21
22	Nature Fresh	Idukki	Sothern High range	9

III. Results and Discussions

Table 2 : Details of the PPP Models with Women Empowerment Goals

Sl. No.	Name of the model	Major activities	Major Partners involved			Mode of partnership (with years)
			Public	Private	Others (If any)	
I. Research domain						
1	Cadbury-KAU Cooperative Cocoa Research Project	Development of Cocoa varieties & agronomic practices, training women for self employment by value addition in cocoa	Kerala Agricultural University, Department of Biotechnology, GOI	Cadbury, India	Nil	MOU (1987-2011)
II. Development domain						
1.	Thirumadhuram-pineapple project	Technical support through training, supply of subsidised inputs & buy back	Poverty Alleviation Mission, State Department of Agriculture	Nadukkara Agro-Processing company	LSG	MOU (2009-11)
2.	Subicsha Coconut Produce Company Ltd	Entrepreneurship development and self employment	Swarna Jayanthi Gram Swaroasgar Yojana, GOI, CPCRI, CFTRI, IIM, Kozhikode, Govt of Kerala	Subicsha Coconut Produce Company Ltd	LSG, Rubco marketing agency	MOU (2003-11)
3.	Sevasram organic enterpise	Promotion of Organic Products	Coconut Development Board, NABARD,	Sevashram, NGO	KILA	Formal MOU (2000-11)
4.	Samagra-Banana project	Capacity building & skill development for self employment	Rural Business Hub scheme, GOI	Provins Agri Systems	LSG	MOU (2000-11)
5.	Uravu RSVY Micro Enterprises	**Common Facilities Centre** for bamboo enterprises through training & market support	Rashtriya Sam vikas yojana, GOI, Tribal Welfare Department of Govt. of Kerala,	Uravu Indigenous Science & Technology Study Centre-NGO, & Eco-link Ltd	LSG	MOU (2004-09)

Based on the weighted scores (Table-1) obtained six PPP models of women empowerment with scores above 25 that reflected high elements of PPP was selected for detailed study. The selected models comprised of Cadbury-KAU Cooperative Cocoa Research Project (28), Thirumadhuram Pineapple

Project (26), Uravu RSVY Micro Enterprises Project (28), Sevashram Organic Producer Company (26), Subicsha Coconut Producers' Company Ltd (28) and Nendran Banana (Samagra) Project (32). The selected six models were broadly categorised into two types based on focal thrust on research and development domains (Table 2). Accordingly, Cadbury-KAU Cooperative Cocoa Research Project (CCRP) came under the domain of PPP model with research objectives whereas all the other five were aimed at socio-economic empowerment of women groups through entrepreneurship development. Results from Table 2 indicated the type of activities and major partners involved in the different PPP models. The major Public agencies that fostered private partnership in the state for women empowerment were State Poverty Alleviation Mission (Kudumbasree) of the government of Kerala, Programmes of Government of India, Kerala Agricultural University, Coconut Development Board and State Department of Agriculture. Minor public partners included Central Plantation Crops Research Institute (CPCRI), Indian Institute of Spices Research (IISR), Kerala Institute of Local Administration (KILA), Department of Bio-Technology (DBT), Central Food Training and Research Institute (CFTRI), Indian Institute of Management (IIM), Kozhikode and National Bank for Agriculture and Rural development (NABARD). The private partners that shared critical responsibilities in pursuing the objectives through formal instruments of partnership were Prowins Agri System, Thiruvanathapuram; Uravu, Wyanadu; Subicsha, Kozhikode; Sevashram, Ankamali; Nadukkara Agro processing Company, Moovattupuzha and Cadbury India Pvt. Ltd, Ernakulam, Eco-Link Wyanad and AV Thomas and Company, Alwaye. An important feature shared by most of these models was the facilitation role served by local self governments and Cooperative marketing agencies like Rubco in its activities. This added a participatory component to the whole process which is seldom found in common PPP initiatives. In order to have a better understanding an attempt has been made to classify the five development models (research model was excluded) based on the value creation processes followed as perceived by members and community.

Table 3 : Value Creation in Development PPP Models

Name of PPP Model	Value creation for the group (n=150)in terms of			Value creation for the society (n=100)in terms of			Average score for the model (%)
	Economic gain (%)	Empowerment (%)	Average for group	Social gain (%)	Environment (%)	Average for society	
Thirumadhuram-pineapple project	72.3	44.67	58.49	58.51	38.49	48.5	53.50
Subicsha Coconut Produce Company Ltd	53.3	35.04	44.17	51.16	23.45	37.31	40.74
Sevasram organic enterprises	49.6	40.65	45.13	30.44	41.46	35.95	40.54
Samagra- Banana project	73.3	56.80	65.05	57.91	44.51	51.21	58.13
Uravu RSVY Micro Enterprises	46.3	45.56	45.93	42.13	26.74	34.44	40.19

a) Classification of PPP Models

Five development models of PPP viz. Subicsha, Samagra, Uravu, Sevashram and Thirumadhuram identified from the state had the triple bottom line objectives of social and economical goals of women empowerment along with local resource use optimization often shared by social enterprises (Haugh, 2007; Martin and Osberg, 2007). However, unlike commercial enterprises, being profitable remained a necessary precondition for these models for achieving their social and environmental goals rather than for economic sharing. Therefore, the distinctive domain of these models and their logic of actions followed could be evaluated only in terms of value creation strategies followed for socio-economic and environmental impact processes for optimizing returns as suggested by Mizik and Jacobson (2003).

In fact, value creation goes beyond economic gains and stressed environmental impact and utility of the activities under taken for the society after accounting for the resources used in the activity. The identified models followed different strategies in balancing these mutually exclusive goals of economics, empowerment and environment. Average economic and empowerment gains in per cent for the group members and socio-environmental gains for the society for the models studied is given in Table-3. The results indicated uniformly higher per cent gains around and above 50% for Samagra and Thirumadhuram models of PPP on value creation dimensions for both group members and society. However, the overall percentage gains of value creation for Subicsha, Uravu and Sevashram models for both group members and society was around 40%, much lower compared to the other two models.

Moreover the value creation gains for group members were uniformly higher than the value creation gains for the society in these models.

The overall percentage gain was used in classifying the selected models into two categories of women entrepreneurship development models Viz. Public dominated welfare models (Eg: Samagra, Thirumadhuram) and Private dominated employment models (Eg: Subicsha, Uravu and Sevashram). The categorization was based on the identified tradeoffs in terms of the emphasis they place on value creation in terms of income generation and socio-environmental benefits as evident from Table.3

i. *Public Dominated Welfare Models*

Your paper text Samagra- Banana project and Thirumadhuram-pineapple project had 58 and 53% overall gains in value creation with reasonable gains on value creation attributes for both group members and the society. It suggests that though an appropriate level of value appropriation was critical for sustainable growth of all these models dichotomy between value creation and value appropriation was not well defined in these public dominated welfare models. Skewed towards total value creation, these models focused on activities that had high value both for the group and society like organic farming, maintaining safe-to -eat standards in value addition and local resource use. Value appropriation loses on these grounds were compensated through incentives and subsidies through public funding as part of the development schemes. These models had high level of community partnership through Panchayathi Raj institutions, farmer organizations and women self help groups that helped in better resource mobilization and conflict resolutions. Often implemented as part of development schemes, the private partnership component had no formal agreements or MOU but functioned mostly on mutually agreed principles. The programmes were focused on overall capacity development and empowerment through nonformal education strategies. Risk minimization and resource optimization was stressed over profit maximization. However, the public dominated welfare models had less sustainability when compared to the private dominated employment models as the value appropriation strategies mostly depended on public funds. These were mostly push-driven models evolved as part of development programmes initiated by departments rather than felt needs of the beneficiaries. Once the project period was over there were not many backup programmes for the continuation or diversification of the activities under the project and often lost direction and relevance.

ii. *Private Dominated Employment Models*

Private dominated employment models consisted of wage employment models (Eg: Sevashram) and self employment models. (Eg: Uravu, Subicsha) based on the emphasis they place on value creation and appropriation. Wage employment models were more market oriented and stressed value appropriation retaining value creation at critical levels for achieving social enterprise status. But, the self employment models were more inclined towards value creation for social impact retaining value appropriation at levels sufficient for sustainability and growth.

Functional economic partnership between public and private partners was present as the funding and monitoring of the programmes were done by the Government and implementation by the private partner. They were mostly projects developed based on local need assessments and as such termed as pull-driven models. They had higher level of sustainability as compared to the public dominated models as they tried to stress value appropriation objectives that focussed profit maximization at critical levels of value creation. But most of these models were aimed at capacity development for production related to the market and prices of products were fixed at points that maximized returns. Local self government, the public domain community partners' participation in these private dominated models was limited to social mobilization and legitimization. Social mobilization followed the blanket method of selection of participants and no aptitude tests were conducted for the selection of participants even for skilled enterprises like bamboo crafts which affected the overall efficiency. The lack of skill among the members often created problems in meeting the breakeven point in a given period. Moreover, there was no provision for hand holding support for tiding the initial phase of skill development in the project funding leading to wage employment status of projects like sevashram.

IV. Conclusion

The results indicated that many of the women entrepreneurship development programmes had components of public private partnerships through formal and informal modalities. This needs to be strengthened through written published MoU that formalise and ensure transparency in the partnership between the private sector and government institutions. The results also established the potential of PPP to break the inefficient paradigms that separated the public and private sectors. All the identified models had community sector organizations, private business partners and public sector organizations that collaborated, competed and learned to serve marginalized women in agriculture sector. It served beyond the goals of welfare by public domains and profit by private concerns by facilitating the convergence of their core assets through the leveraging support of local administration and community organizations. It also opened up the possibilities of conceptualisation of

SHGs as social enterprises in development. The partnerships enabled product diversification, quality enhancement and convergence of activities of different departments and agencies. Scaling up of enterprise activities to bring economies of scale and ensuring market and employment opportunity for marginalised women could also be ensured in these models. The results proved value creation as an appropriate quantitative parameter in evaluating the SHGs and group enterprises in social sector. Quantification of appropriate threshold levels of value creation for sustainability of groups can open new avenues of research in the area. Moreover, the results proved the tremendous potential of PPP in entrepreneurship development in women SHGs and the need for promoting it as a major policy instrument especially in the context of decentralization. PPP also strengthened the systems of cooperation, collaboration and networking in women SHGs, and it could be promoted in the frame work of a social enterprise that goes a long way in adopting it as a development strategy. Such action includes strengthening the capacity of public institutions and NGOs to improve the knowledge of women's changing forms of involvement in farm and other activities.

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Soil Solarization, an Eco-Physiological Method of Weed Control

By Pritam Ghosh & Ashim Kumar Dolai
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Need for Soil Solarization- Weeds are the plants growing out of a place where they are not desired for a particular period of time. Weed problems have turned into a continuing struggle for farmers on account of the pressure to raise crops and maximize crop production to meet increasing demand of the fast growing human population. Weeds are the scarce and silent robbers of plant nutrients, soil moisture, solar energy and also occupy the space which would otherwise be available to the main crop; harbour insect-pests and disease causing organisms; exert adverse allelopathic effects; reduce quality of farm produce and increase cost of production. Weeds, unlike other pests, are omnipresent and account for at least one-third of this loss. Losses due to weeds are higher than those from insects and diseases – insects 30%, weeds 45%, diseases 20%, other pests 5% (Rao, 2000). Therefore, efficient weed management approach is expected to contribute significantly in sustaining agriculture. There are several methods for controlling weeds such as cultural method, manual and mechanical method, chemical method, allelopathy and integrated approach. The most practised one is hand weeding but it is laborious, time-consuming, costly and also is not feasible under all situations. Now-a-days, for effective and economic weed control, herbicides are gaining popularity among the farmers. Out of total pesticide use, 17% is herbicides.

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Soil Solarization, an Eco-Physiological Method of Weed Control

Pritam Ghosh [α] & Ashim Kumar Dolai [σ]

I. Need for Soil Solarization

Weeds are the plants growing out of a place where they are not desired for a particular period of time. Weed problems have turned into a continuing struggle for farmers on account of the pressure to raise crops and maximize crop production to meet increasing demand of the fast growing human population. Weeds are the scarce and silent robbers of plant nutrients, soil moisture, solar energy and also occupy the space which would otherwise be available to the main crop; harbour insect-pests and disease causing organisms; exert adverse allelopathic effects; reduce quality of farm produce and increase cost of production. Weeds, unlike other pests, are omnipresent and account for at least one-third of this loss. Losses due to weeds are higher than those from insects and diseases – insects 30%, weeds 45%, diseases 20%, other pests 5% (Rao, 2000). Therefore, efficient weed management approach is expected to contribute significantly in sustaining agriculture. There are several methods for controlling weeds such as cultural method, manual and mechanical method, chemical method, allelopathy and integrated approach. The most practised one is hand weeding but it is laborious, time-consuming, costly and also is not feasible under all situations. Now-a-days, for effective and economic weed control, herbicides are gaining popularity among the farmers. Out of total pesticide use, 17% is herbicides. The compound growth rate of herbicide consumption has been 13.7% against – 3.88% of insecticides for the last one decade (Aulakh, 2005). But the continuous use of herbicides poses many problems such as, it

1. causes health hazards
2. pollutes the environment
3. contaminates drinking water
4. contaminates the soil and terrestrial system
5. contaminates food and agricultural produces
6. contaminates aquatic and marine products
7. causes toxicity to the succeeding crop
8. develops resistance in weeds
9. causes shift in weed flora.

Therefore, interest in non-chemical approaches which aim to reduce pesticide usage is growing. So, there is a great necessity for the development of alternative non-hazardous means of weed management. In this light, harvesting of solar energy through soil solarization for controlling weeds is a potential step to reduce the dependence on chemicals.

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II. Soil Solarization an its Mechanism

Soil solarization is a method of hydrothermal disinfestation by covering moist soil with transparent polyethylene film during the hot summer months. The basic principle behind weed control through soil solarization is built up of lethally high temperature in top soil where most of the dormant and viable weed seeds are present (Soumya et al.,2004). In agriculture, polyethylene mulches with black polyethylene sheets have been used as a post-planting treatment to obtain good control of weeds. However, in solarization transperant polyethylene sheets are used as a pre-planting treatment. Soil solarization was first described in 1976 by Katan and Co-workers in Israel. It involves mulching of the soil with transparent polyethylene films so as to trap the solar heat in the surface soil and thereby increasing the temperature. The common mulch used for solarization is transparent polyethylene and in some cases polyvinyl chloride. The efficiency of solarization depends on the type of the material used for solarization and its thickness. Transperant polyethylene sheets perform better than black polyethylene (Biradar et al.,1997). Transparent polyethylene sheets of 0.05 mm thickness are superior to 0.075 and 0.10 mm thick ones (Mudalagiriyappa et al.,1999, Biradar and Hosamani 1997). Soil solarization is a hydrothermal process, which brings about thermal and other physical, chemical and biological changes in the moist soil during and even after mulching (Stapleton and DeVay, 1986). Global radiation is composed of short-wave solar radiation and long-wave terrestrial radiation. The short-wave solar radiation passes through the transparent polyethylene sheet but the long-wave terrestrial radiation is held back resulting in trapping of the heat in the soil and thereby increasing the soil temperature, lethal to the soil-living pathogens, nematodes and weeds etc. Water evaporating from the moistened soil surface will condense on the inner side of the mulch and drip back to the soil surface. These water droplets on the inner side of the mulch will trap the long-wave radiation and thus prevent cooling of the soil surface. In order to reduce heat losses through sensible and latent heat

fluxes, the plastic mulch has to be kept intact (Mahrer et al., 1984).

III. Effect of Soil Solarization on Weeds

The possible mechanisms of weed control by soil solarization are breaking dormancy of weed seeds and solar scorching of emerged weeds, direct killing of weed seeds by heat and indirect microbial killing of weed seeds weakened by heating. It may also reduce germination of weeds (Lalitha et al.,2003). The temperature due to solarization is maximum at soil surface and it decreases with the depth of the soil(Shukla et al., 2000). Therefore, the weed seeds buried deep in the soil may survive.Soil solarization reduces intensity of all types of weeds – monocots and dicots (Mudalagiriyappa et al.,1999). Unlike other methods of weed control which are mostly curative, soil solarization is a preventive method where it helps to deplete reserves of dormant weed seeds in soil which otherwise provide a source of seeds for persistent weed problems that often require repeated control measures. The following recommendations should be followed under adequate climatic conditions (Katan, 1981) –

1. Transparent polyethylene sheet instead of black polyethylene sheet should be used since it transmits most of the solar radiation that heats up the soil.
2. Soil mulching should be carried out during the period of high temperature and intense solar radiation.
3. Adequate soil moisture is necessary during solarization to increase the thermal sensitivity, improve heat conduction in the soil and enable biological activities. Saturated soil is optimal for this purpose.
4. The thinnest polyethylene sheet should be used as it is both cheaper and more effective in heating due to better radiation transmittance than the thicker one.
5. Since the temperature at the deeper soil layers are lower than that at the upper ones, thus extending the solarization period usually for four weeks or longer, enable control at deeper layer.

IV. Effect on Soil Microflora

It has been reported that soil solarization affects the soil-microflora even though the effects are selective. Due to solarization, changes occur in the population of soil micro-organisms. Solarization causes increase in temperature and at higher temperature only a few species are able to survive close to the upper limit of temperature for that group. No eucaryotes are known to grow at temperatures above 60 – 61.5^{0}C. Among the microflora, soil borne fungi suffers most followed by actinomycetes and bacteria (Zaid et al.,1990, Sharma et al.,2004))

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Determinants of Agricultural Export Trade: A Co-Integration Analysis for Cotton Lint Exports from Chad

By David Boansi
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Abstract- Following the dramatic decline in Chad's performance for production and export of cotton lint (from leading producer and among leading exporters in the 1960s to being at the bottom in rank among the C-4 countries of WCA since 1998), use is made of the Johansen Full Information Maximum Likelihood test to identify and estimate the magnitude and effects of key determinants of exports from the country. In this regard, I defined and estimated two primary co-integrating and error correction equations using volume and value of exports as dependent variables in the respective equations. Diagnostic tests performed revealed that the estimates observed are stable, and residuals for the respective models are normally distributed, non-serially correlated and homoscedastic. Results of the study show that cotton production, competitiveness of the country in exports of the commodity, volume of world exports of the commodity, and export price faced by the country are key determinants of export growth. Policies implemented in both the internal and external environments are noted to have had more harmful than beneficial implications for the cotton industry.

Keywords: *co-integration; cotton lint; determinant; export growth; international trade; chad.*

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Keywords: co-integration; cotton lint; determinant; export growth; international trade; chad.

I. Introduction

Agricultural export trade has received much international attention due to fragile nature of the sector, volatile nature of world prices for agricultural commodities, and to trade distortions induced by major players in various agricultural commodity markets. The world cotton market is one of the numerous agricultural markets that have attracted and received immense research attention over the past two to three decades. Majority of the researches conducted so far in this regard have focused on identifying relevant implications of subsidies and other distortions on trade and on farm-households and exporters in agriculture-founded economies, notably the C-4 countries of WCA (namely Burkina Faso, Benin, Chad and Mali). Majority of such studies have through simulations of price impact, specifically of cotton subsidies, confirmed losses to exporters, marketers and farmers in the aforementioned countries and elsewhere (Alston and Brunke 2006; Goreux 2003; Anderson and Valenzuela 2006). Dedication of time and energy towards identifying implications of such distortionary measures on the economies of these countries is due to the fact that, downward pressure induced on world cotton prices harms millions of households and over 10 million people across West and Central Africa region (Alston et al 2007). Although distortionary measures on the world cotton market are believed to harm farmers and exporters in all the C-4 countries and other developing economies, emphasis in this study would be placed on Chad as an entity/country whose cotton production and export industry has in the midst of such distortions and domestic inefficiencies witnessed a more or less continuous decline in performance since the year 1997 even when other countries in the region (e.g. Mali and Burkina Faso) witnessed significant increases in these indicators along the line. Chad has lost its stand of being the highest producer and among the leading exporters in the C-4 during the 1960s and 1970s to being at the bottom in rank among the four countries in terms of cotton production and exports.

Previously deemed an agrarian economy, Chad has attracted much international and local attention since the year 1928, following the introduction and cultivation of cotton in the country. From virtual non-existence in the pre-1928 period, cotton production in the country grew steadily to 40,000 tonnes during the early 1960s, making the country the leading producer in West and Central Africa (Baffes 2007). Since its introduction, cotton has played and continues to play relevant roles in the Chadian economy. Besides income generation for farmers through production, processing and domestic marketing, cotton exports in the form of lint (about 96 percent of total production) facilitates earning of foreign exchange and generation of government revenues through taxes on local production.

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The cotton industry employs over 40 percent of the country's total population (about 2 million people). Although in decline, the cotton sector as of the year 2007 accounted for 20 percent of the country's total merchandize exports and 2.4 percent of GDP in 2001-2003 (Baffes 2007). By estimates of the FAO, cotton lint exports accounted for 42.09 percent of total value of agricultural exports from the country during the period 2005-2011. Due to the important role cotton played in the Chadian economy during the late 1920s to 1970s, the industry received great amount of attention from various stakeholders (including Cotontchad, DAGRIS and the local private banking sector). Supports in various forms helped increase not only production, but as well paved room for value addition and exports.

Until the year 2003, where crude oil displaced cotton as the key source of income for the government, the cotton sector served as the basic foundation for development of the Chadian economy. Following recession in the world cotton market between 1991 and 1993 however, most of the initiatives used for stimulating growth in the Chadian cotton sector (including stabilization of prices paid to peasant producers) were withdrawn. The decline in world cotton prices in 1985, the recession of 1991-1993, existing domestic inefficiencies, and downward pressure on world cotton prices due to continuous use of subsidies by major players on the world cotton market among other factors have pulled Chad from its reputable position in cotton production and exports during the 1960s to 1970s, to being the least in production and exports among the C-4 countries. As shown in figure 1, volume of exports of cotton from the country decreased from 72,000 tonnes in 1997 to as low as 10,462 tonnes in 2010 (increasing thereafter to 14,995 tonnes). The corresponding figures for the years 1997 and 2010 in terms of value are respectively $113,000 (thousand) and $18,000 (thousand) (increasing thereafter to $41,921(thousand) in 2011). In spite of all attempts by the government to revive the sector since the year 2000, there is yet to be seen any major improvement in the sector's production and exports of cotton (most importantly cotton lint exports as it represents approximately 96 percent of the country's cotton production). It is in this regard, that I source identification of key determinants of cotton lint exports from Chad to help inform policy prescriptions on relevant agricultural and trade policies needed. In achieving this however, I employ the Johansen Full Information Maximum Likelihood test (for co-integration analysis). This approach facilitates estimation of both short- and long-run effects of key determinants of exports.

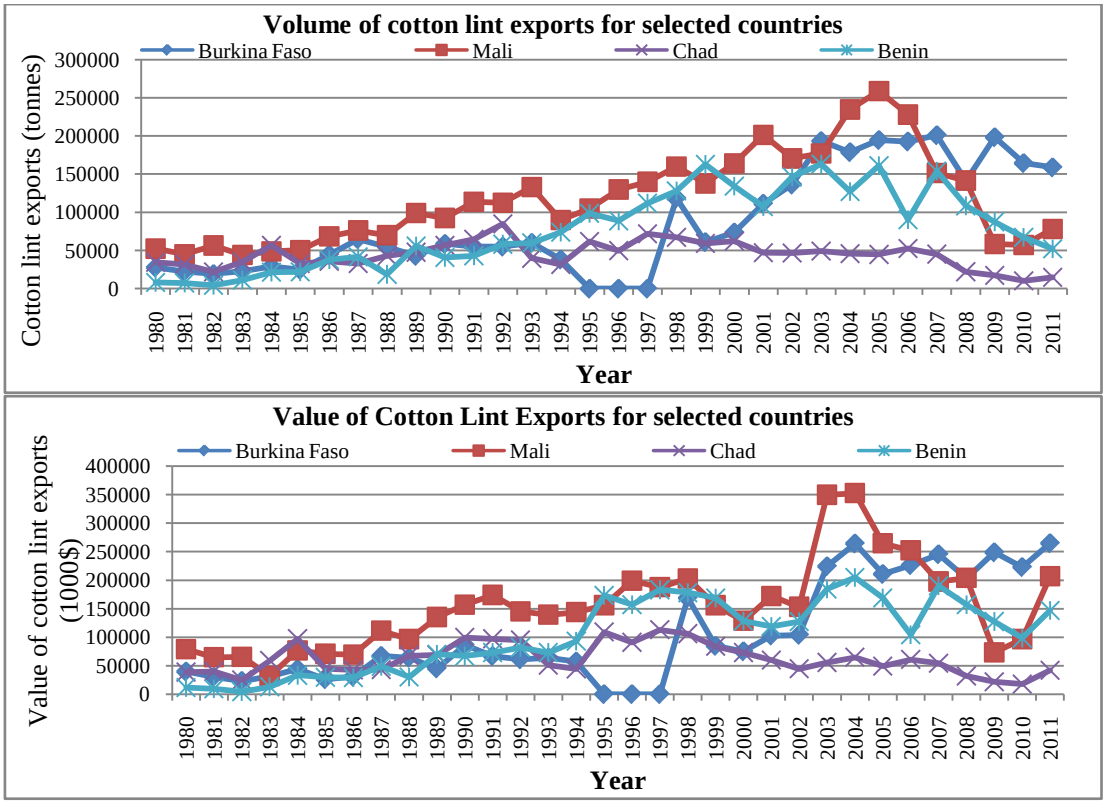

Figure 1 : Trends in Volume and Value of Cotton lint Exports from C-4 Countries in West and Central Africa
Data Source: Agricultural Trade Statistics of FAO (FAOSTAT)

II. Literature Review

Knowing and understanding the mechanisms through which various economic and policy drivers influence exports is key to drafting and implementing appropriate trade policy measures to further stimulate exports and shield domestic industries from potential adverse implications of developments in international markets. Efforts made so far towards determining drivers of exports for various agricultural commodities have yielded quite interesting findings in economic, business and trade literature. In as much as some of the findings conform with economic and trade theories, others are either mixed signals or tend to disprove existing theories. In a study to assess the effect of agricultural and financial sector reforms on export of cotton lint from Pakistan, Anwar et al (2010) revealed that export of cotton lint is positively driven by increasing world demand for cotton, export competitiveness of the country, and increase in trade openness. In a study on performance, destinations, competitiveness and determinants for export of cucumber and Gherkin from India, Kumar et al (2008) discovered that a one percent increase in volume of international trade in the commodities under study leads to a 5.96 percent increase in demand for exports from India. Similarly, Kumar and Rai (2007) found a positive significant association between tomato exports from India and volume of international trade. Although increased production in an open economy is believed to stimulate export growth, Kumar and Rai (2007) found a significant negative association between exports of tomato and India's production of the commodity. In determining the key drivers of exports for fruits and vegetables from sub-Saharan Africa, Takane (2004) discovered that exports are driven by growing foreign demand, relatively short flight time, price competitiveness and market liberalization policies.

In contrast to the discovery by Kumar and Rai (2007) on the association between exports and production however, Nwachukuet al (2010) found a significant positive association between exports of cocoa and production for Nigeria. Apositive association between national exports and world volume of exports (as proxy for international trade) was however affirmed in this study as well. In a study on comparative analysis of economic reform and structural adjustment programme in Eastern Africa, Ngeno (1996) discovered that export growth is positively related to output level since higher production leads to increased export volumes. Similarly, Ball (1966) discovered that higher production stimulates export growth, while higher domestic demand dampens export growth. In investigating the determinants of export growth rate in Uganda for the period 1987-2006, Agasha (2009) found a significant negative association between foreign price level and exports in the long-run. This effect was deemed a mixed signal. In the short-run however, Agasha found a significant positive effect of foreign price on export growth at the second and third lags of foreign price level. In a similar study in Tanzania, Ndulu and Lipumba (1990) revealed that foreign prices of primary commodities significantly affect the export performance of country's involved in their production. Edwards and Golub (2004) also found a significant positive association between export supply for South Africa and foreign prices.

III. Methodology

a) *Analytical Framework*

Following trade liberalization in most developing countries and implications thereof, efforts have been made to assess responses of production and export dimensions forvarious industries worldwide to help inform policy decisions on implication of changes in some key development indicators. In such research and analytical efforts, one key technique that has received tremendous attention in economic, business and trade literature is co-integration analysis. This technique, unlike other approaches used to assess supply and production responses, helps in estimating both short- and long-run implications of changes in relevant development indicators. Three main approaches have been proposed in literature for performing co-integration analysis. These are the Engle-Granger two-step estimation technique (Engle and Granger 1987), Phillips-Ouliaris residual-based test (Phillips and Ouliaris 1998) and the Johansen Full Information Maximum Likelihood test (Johansen and Juselius 1990). Although deemed simple, intuitive and easy to perform, the Engle-Granger approach is flawed by small-sample biases (Stock, 1987; Bannerjeeet al 1986). This drawback is partly attributed to the fact that, in producing long-run estimates in the first stage, the approach tends to ignore short-run dynamics, thereby producing short-run estimates that are not guided by long-run estimates. This precludes potential consistency in estimates. In addition, both the Engle-Granger approach and the Phillips-Ouliaris residual-based test hold unto the assumption of a single co-integrating equation between variables, regardless of the number of variables considered in a system. This however does not reflect reality on the ground. In studying economic relationships, there exists a high probability of identifyingn-1 number of co-integrating equations between n variables. These flaws of the Engle-Granger and the Phillips-Ouliaris approaches are appropriately addressed through the use of vector co-integration techniques, noted amongst which is the Johansen Full Information Maximum Likelihood test. Accordingly, I employ the Johansen technique for my analysis.

The Johansen approach to co-integration analysis commences with the definition of a vector auto-regression given as follows:

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_p X_{t-p} + \mu_t \qquad (1)$$

Where X_t represents an *(n×1)* vector of $I(1)$ (non-stationary) variables, Π_1 through Π_p represent (m×m) matrix of coefficient, and μ_t is *(n×1)* vector of innovations (white noise errors). Following definition of the vector auto-regression, appropriate lags are selected to guide identification of the number of co-integrating equations. Selection of appropriate lag order is sourced through the use of Akaike Information Criterion, Schwarz Criterion (SC) and the Hannan-Quinn Information Criterion (HQ). Lag order selected in this stage guides identification of the number of co-integrating equation(s) in the immediate succeeding stage. Test for the number of co-integrating equations is performed using two likelihood ratio (LR) tests proposed in economic, business and trade literature. These are the trace test statistic and the maximal-eigenvalue test. The trace test is a joint test of the null hypothesis of r co-integrating vectors against the alternative that it is greater than *r*. The trace test statistic is expressed as follows:

$$Jtrace(r) = -T \sum_{i=r+1}^{p} ln(1 - \lambda_i) \qquad (2)$$

On the other hand, the maximal-eigenvalue test conducts separate tests on the individual eigenvalues for a null hypothesis that the number of co-integrating vectors is r, against an alternative of r+1. The maximal-eigenvalue test statistic is expressed as follows:

$$Jmax(r, r+1) = -T\, ln(1 - \lambda_{r+1}) \qquad (3)$$

Of these two likelihood ratio tests, the trace test according to Harris (1995) shows more robustness to both skewness and excess kurtosis in the innovations than the maximal-eigenvalue test. Accordingly, the trace test has been mostly used over the maximal-eigenvalue test in identification of co-integration equation(s). Confirmation of co-integrating relationships between variables in a system renders the vector auto-regression (VAR) model as specified in equation (1) inappropriate setup. In its stead, a special parameterization that supports analysis of the co-integrating structures is considered. This is primarily achieved through subtraction of Xt-1on both sides of equation (1). The resulting model is termed a vector equilibrium model (Lütkepohl and Krätzig 2004) or vector error correction model, and is expressed as follows:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{p-1} \Delta X_{t-p+1} - \Pi X_{t-p} + \mu_t \qquad (4)$$

$$\Gamma_1 = \Pi_1 - I,\ \Gamma_2 = \Pi_2 - \Gamma_1,\ \Gamma_3 = \Pi_3 - \Gamma_2,\ \text{and}\ \Pi = I - \Pi_1 - \Pi_2 - \ldots - \Pi_p$$

In contrast to the $I(1)$ (non-stationary) status of X_t in equation 1, ΔX_t in equation (4) is $I(0)$ (stationary) . In this regard, i= 1,2,…,p-1 are all stationary and u_t assumed to be $I(0)$ as well. For the equation to be valid and meaningful, ΠX_{t-p} must also be stationary. In the above specification, the matrix Π determines the extent to which a given system is co-integrated and is referred to as the impact matrix (Ssekuma 2011). The matrix Π can further be decomposed into two unique sub matrices α and β, where α measures the rate at which deviations from the long-run equilibrium are restored in the current period (speed of adjustment of the system under study –also called the error correction coefficient) and β contains r co-integrating vectors. Γ_i in equation (4) represents short-run estimates, while Π contains the long-run estimates. In performing co-integration analysis however, all variables considered in a system are a priori treated endogenous unless some variables are found stationary at level. In the latter case, should the variables be perceived to have significant effect on the long-run co-integrating space and affect the short-run model, there arises a need to assume such variable(s) exogenous. In such situation, equation (4) can be re-written as follows (Kuwornuet al 2011):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{p-1} \Delta X_{t-p+1} - \Pi X_{t-p} + vD_t + \mu_t \qquad (5)$$

Where D_t represents the stationary *(I(0))* variable(s). To appropriately capture rich dynamics in the system under study, Lütkepohl and Krätzig (2004) proposed the use of fewer but relevant variables. They debated that increasing the number of variable and equations (through use of inappropriate lags) does not generally lead to better model, but rather, it complicates things and precludes appropriate capturing of the dynamic, inter-temporal relocations between the variables considered. Along this same line of reasoning, Harris and Sollis (2003) advice the use of variables that have a high probability of affecting the short-run behavior of the model.

b) Model Specification

Although several indicators have been proposed in trade literature to affect exports of various agricultural commodities, in this study I stick to the use of fewer but relevant variables among the lots noted in literature. I however estimate two separate models. In Model 1, I set volume of cotton lint exports as the dependent variable and value of exports as the dependent variable in Model 2. The respective models are accordingly expressed as follows:

$$ln\,(EXPVol) = f\,(ln(EXPPRICE), ln(PROD),\ ln(CEP), ln(EXPVolW)) \qquad (6)$$

$$ln\,(EXPVal) = f\,(ln(EXPPRICE), ln(PROD),\ ln(CEP), ln(EXPVolW)) \quad (7)$$

Where

$ln\,(EXPVol)$ –log of volume of cotton lint exports from Chad

$ln\,(EXPVal)$ -log of value of cotton lint exports from Chad

$ln\,(EXPPRICE)$ -log of cotton lint export price for Chad

$ln\,(PROD)$ -log of cotton lint production (output) for Chad

$ln\,(CEP)$ -log of the comparative export performance index for Chad in cotton lint

$ln\,(EXPVolW)$ -log of world volume of cotton lint exports

In as much as various research works have made use of average world price as proxy for export price, I deem this inappropriate. This stand I take is justified on the grounds that, in spite of the world price quoted on the international markets for exports of various commodities, countries face different prices based on the quality of the products they export (with some attracting premiums in the process), their primary destinations and on their respective performances. In this regard, I make use of the export price faced by exporters from Chad instead of the world market price quoted on various websites. The export price for cotton lint from Chad is calculated as follows:

$$EXPPRICE = \frac{EXPVal}{EXPVol} \times 1000 \quad (8)$$

The outcome represents the export price of cotton lint in $/tonne. I multiplied the primary fraction by 1000 because value of exports reported by the agricultural trade statistics on the FAO is in $1000, while the volume of exports is in tonnes. The comparative export performance index (CEP) is as well computed using the following formula:

$$CEP = \frac{(X_{IB}/X_B)}{(X_{iA}/X_A)} \quad (9)$$

Where

X_{iB} - value of cotton lint exports from Chad

X_B - total value of agricultural exports from Chad

X_{iA} - value of world exports of cotton lint

X_A - total value of world agricultural exports.

In line with specifications by Shende and Bhole (1999), Kumar et al (2008) and Nwachukuet al (2010), I include world volume of cotton lint exports to help capture implication of changes in international trade and demand on exports from Chad. Exclusion of nominal exchange rate from equations (6) and (7) is due to the fact that, with the exception of Ghana, and possibly other few countries (including Nigeria), all other countries in Central and West Africa have the same nominal exchange rate due to use of the CFA franc. By this, nominal exchange rate fails to reflectas a unique surrogate measure of incentive for Chad over the other countries that use the same currency. Developments in export from Chad are possibly driven by external factors and by internal factors that are unique to Chad as a country. Besides own computations as shown in equations (8) and (9), data for all other variables were gathered from the agricultural production and trade database of FAO (FAOSTAT) for the period 1983-2011.

IV. Results and Discussion

Prior to discussing results for the respective long- and short-run models, effort is made in this section to provide some descriptive statistics on the variables considered in the models. In addition I provide information on outcome of the data verification process through a unit root test (in other to ascertain the order of integration of the respective data series), lag order selection and test of co-integration. Output for the models are then presented and discussed afterwards. Accordingly, this section is structured into four parts, starting with the descriptive statistics.

a) Descriptive Statistics

In contrast to the closeness of mean and median for all the variables considered, I note a wide variation between the maximum and minimum values for all the variables. For the six variables considered, the greatest variations are in volume of exports, value of exports, production and the index of competitiveness (comparative export performance index). Over the period 1983-2011, the maximum, minimum and mean values of export are respectively $113,000.00 (thousand), $18,000.00 (thousand) and $65,208.10 (thousand). The corresponding volumes are 85,000.00 tonnes, 10,462.00 tonnes and 46,050.07 tonnes respectively. The country has over the aforementioned period observed a mean export price of $1,448.12/tonne. For the maximum and minimum, the country observed export prices of $2,795.67/tonne and $952.74/tonne respectively.

Table 1 : Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.
EXPVal	65,208.10	60,000.00	113,000.00	18,000	26,629.65
EXPVol	46,050.07	46,906.00	85,000.00	10,462.00	17,367.20
EXPPRICE	1,448.12	1,411.77	2,795.67	952.74	348.65
PROD	54,436.31	57,938.00	103,236.00	16,500.00	19,956.71
CEP	29.08	31.34	44.40	11.78	8.42
EXPVolW	6,058,783.00	5,815,793.00	9,094,328.00	4,136,978	1,383,953.00

Throwing some light on production of cotton lint in Chad for the period 1983-2011, the country observed a mean output of 54,436.31 tonnes, a maximum of 103,236.00 tonnes and a minimum of 16,500.00 tonnes. Reflecting index of competitiveness (competitive advantage), the country observed a maximum comparative export performance index of 44.40 and minimum of 11.78. This indicates that the country has over the entire period had a strong competitive advantage in exports of cotton lint. A mean index of 29.08 was as well observed. As a measure of international trade and world demand for cotton lint, a mean export volume of 6,058,783.00tonnes of cotton lint was observed globally over the period 1983-2011. Respective maximum and minimum volumes of 9,094,328.00tonnes and 4,136,978.00 tonnes were as well observed.

b) Data Verification through Unit Root Test

For there to exist any long-run association between variables in a system, the variables involved are primarily expected to be integrated of the same order. In ascertaining the order of integration of variables, use in literature has been made of several unit root test approaches including the Dickey-Fuller (DF) test, Augmented Dickey-Fuller (ADF) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, Ng-Perron modified unit root test, unit root test with structural breaks, and the Phillips-Perron (PP) unit root test. I however in this study make use of the Phillips-Perron (PP) unit root test. The PP statistic primarily represents Dickey-Fuller statistic that has been made robust to serial correlation using the Newey-West heteroskedasticity-and-autocorrelation consistent matrix estimator. In ascertaining the order of integration of the variables, I held unto a linear trend assumption. Thus, a trend and intercept term were included in the test at level, and only intercept term on first difference.

Table 2 : Unit Root Test.

Trend + intercept at level, intercept on first difference

Variables	PP-Stat Level	N-W Bandwidth	PP-Stat 1st diff.	N-W Bandwidth
$ln\,(EXPVal)$	2.584642	4	-5.348980***	2
$ln\,(EXPVol)$	-1.829315	1	-5.348980***	2
$ln\,(EXPPRICE)$	-1.472680	1	-4.337257***	2
$ln\,(PROD)$	-1.685917	2	-6.114367***	4
$ln\,(CEP)$	-3.396113	2	-8.691028***	4
$ln\,(EXPVolW)$	-3.254905	1	-6.597208***	2
Critical value, 5%	-3.580623		-2.976263	

As shown in Table 2, all the variables are found to be $I(1)$. Thus, all the variables are non-stationary at level, but become stationary on first difference (at the 1percent significance level). Accordingly, all the variables are assumed a priori endogenous in the VAR specification for lag order selection and VECM should co-integrating vector(s) be confirmed.

c) Lag Selection and Co-Integration Test

In identifying the appropriate lag order to use for the respective specifications and tests, as shown in appendices 'A' and 'B', the Akaikeinformation criterion (AIC) selected lag order two, while the Schwarz information criterion (SC) and the Hannan-Quinn information criterion (HQ) selected lag order one. Similarly, in as much as the Final prediction error (FPE) as a secondary criterion selected lag order two, the sequential modified LR test statistic selected lag order one. Accordingly, I select lag order one for the VAR models. Subsequent tests for co-integration confirmed the existence of one co-integrating equation for each of the two primary specifications (equation 6 and 7). This confirmation renders the VAR a less appropriate set-up. I therefore make use of a vector error correction model (VECM). The VECM basically consists of a normalized (co-integrating/long-run) equation and an error correction (VAR/short-run) equation. The results for the

respective normalized and error correction equations are presented and discussed in the next section.

d) Results and Discussion of Export Responses

Holding unto a linear trend assumption (to help capture policy implications) and employing the VECM for the analysis based on confirmation of co-integrating vectors, the following normalized (co-integrating) equations were observed for the respective models

Model 1 : Dependent Variable – ln (EXPVol).
Assumption: Linear trend in data (Intercept and trend in CE – no trend in VAR).

$$\mathbf{ln\ (EXPVol)} = -0.173\ \mathbf{ln\ (EXPPRICE)} + 0.461\ \mathbf{ln\ (PROD)} + 0.705\ \mathbf{ln\ (CEP)} + 0.733\ \mathbf{ln\ (EXPVolW)} - 0.039\mathbf{Trend} - 6.273$$

(0.131) (0.080) (0.104)(0.173) (0.005) (10)
(-1.322) (5.747***) (6.779***) (4.244***) (-7.224***)

Model 2 : Dependent Variable – ln (EXPVal).
Assumption: Linear trend in data (Intercept and trend in CE – no trend in VAR)

$$\mathbf{ln\ (EXPVal)} = 0.827\ \mathbf{ln\ (EXPPRICE)} + 0.461\ \mathbf{ln\ (PROD)} + 0.705\ \mathbf{ln\ (CEP)} + 0.733\ \mathbf{ln\ (EXPVolW)} - 0.039\mathbf{Trend} - 13.181$$

(0.131) (0.080) (0.104) (0.173) (0.005)
(6.297***) (5.747***) (6.779***) (4.244***) (-7.224***) (11)

The respective short-run equations are expressed as follows:

$$\Delta \ln(EXPVol_t) = \Gamma_0 + \sum_{i=0}^{n} \Gamma_{1i}\, \Delta ln(EXPVol_{t-1}) + \sum_{i=0}^{n} \Gamma_{2i}\, \Delta \ln(EXPPRICE_t) + \sum_{i=0}^{n} \Gamma_{3i}\, \Delta \ln(PROD_t) + \sum_{i=0}^{n} \Gamma_{4i}\, \Delta \ln(CEP_t) + \sum_{i=0}^{n} \Gamma_{5i}\, \Delta \ln(EXPVolW_t) - \propto (RESIDUAL_{t-1}) \quad (12)$$

$$\Delta \ln(EXPVa\,l_t) = \Gamma_0 + \sum_{i=0}^{n} \Gamma_{1i}\, \Delta ln(EXPVa\,l_{t-1}) + \sum_{i=0}^{n} \Gamma_{2i}\, \Delta \ln(EXPPRICE_t) + \sum_{i=0}^{n} \Gamma_{3i}\, \Delta \ln(PROD_t) + \sum_{i=0}^{n} \Gamma_{4i}\, \Delta \ln(CEP_t) + \sum_{i=0}^{n} \Gamma_{5i}\, \Delta \ln(EXPVolW_t) - \propto (RESIDUAL_{t-1}) \quad (13)$$

From equations 12 and 13, the Γ s indicate short-run effect of changes in the explanatory variables on the explained variables and α represents the speed of adjustment in the system (thus, the rate at which deviations from the long-run equilibrium are corrected for in the current period). A negative and significant α validates the existence of co-integration, and implies that adjustments made in response to deviations from the long-run equilibrium are made towards restoring such equilibrium. Accordingly, the 'RESIDUAL' in equations 12 and 13 represents the error correction term. Diagnostic tests performed for the respective models indicate that the respective residuals are normally distributed, non-serially correlated and homoscedastic. In testing for stability of the coefficients for each of the models, the CUSUM and CUSUM of Squares tests employed (as shown in Appendix C) confirm that the coefficients for each of the models are stable.

In interpreting results for the respective models, the variables included in the models are found to explain about 66.3 percent of the variations in volume of cotton lint exports from Chad, and 73.2 percent of variations in value of exports. Deviations from the long-run equilibrium for volume of exports are found to be corrected faster than those for value of exports. Approximately 98.5 percent of deviations from long-run equilibrium in volume of exports are corrected for in the current period, while about 83.7percent of deviations in value of exports are corrected for in the current period. Negative coefficients of the intercept term in equations 10 and 11 indicate that, should there be no significant improvement in any of the other explanatory variables, both volume and value of exports would continue to decrease in the long-run. The significant and negative coefficients (-0.039) of the trend term in equations 10 and 11, signify that exports (both volume and value) from the country have responded negatively to changes in domestic and international policy environments. This indirectly means that trade policies drafted and implemented over the scope of the study (1983-2011) have been more harmful than beneficial to the cotton export industry of Chad. Over the period, both volume and value of exports are found to decrease by 0.039 units, significant at the 1percent level.

In the long-run, cotton production, comparative export performance index and volume of world exports of cotton lint are found to be the key determinants of volume of exports for cotton lint from Chad. These three variables together with export price are found to be the key determinants of value of exports of the commodity from Chad. One percent increase in output (production) of cotton may lead to a 0.46 percent increase in both volume and value of exports, significant at the 1percent level. Similarly, one percent increase in the index of competitiveness may leads to 0.71 percent increase in both volume and value of exports, significant at the 1% level. Increase in international trade and world demand

for the commodity is noted to stimulate export growth for Chad. This claim is based on the significant and positive coefficient of the world volume of exports. A one percent increase in world volume of exports may lead to a 0.73 percent increases in both volume and value of exports. Although negative, the effect of export price on volume of exports is noted to be insignificant. The positive (0.827) and significant coefficient for export price in equation 11 however indicates that a one percent increase in export price faced by exporters in Chad leads to a 0.827 percent increase in value of exports. By this, export price in the long-run is a key determinant only for value of exports and not volume.

In the short-run however, export price is observed to have quite interesting effects on exports of cotton lint from Chad. In as much as increases in export price significantly stimulate growth in value of exports, they as well dampen volume of exports from the country. These interesting implications could be attributed to the fact that export volumes have over the scope of the study not depicted any major improvements, and in such situations, any increase in price of exports is likely to increase the value of exports. Due to the distortionary induced down pressure on world prices however, increases in export price faced by exporters from Chad potentially leads to trade diversion in favor of exports from countries like the US and India where the commodity is offered at a relatively lower price due to subsidies levied for production and export of the commodity in such countries. In contrast to the long-run implications of production on both value and volume of exports, cotton production in the short-run is found to be a key determinant only for volume of exports, but not value. This again affirms propositions by Ball (1966) and Ngeno (1996) that higher production stimulate growth in volumes of export. The insignificant coefficient of production in model 2 indicates that value of exports for the country is determined more by other internal factors like competitiveness and external factors on the world market than by production.

Table 3 : Output for the Short-Run Equations

Variables	Model 1 Coefficient Std. Error	Model 2 Coefficient Std. Error
$\Delta\ ln\ (EXPVol\ (-1))$	0.233 (0.144)	
$\Delta\ ln\ (EXPVal\ (-1))$		0.130 (0.127)
$\Delta\ ln\ (EXPPRICE\ )$	-0.513** (0.221)	0.547** (0.229)
$\Delta\ ln\ (PROD)$	0.303** (0.133)	0.241 (0.142)
$\Delta\ ln\ (CEP)$	0.835*** (0.142)	0.826*** (0.147)
$\Delta\ ln\ (EXPVolW)$	0.853** (0.328)	0.856** (0.343)
C	-0.067 (0.039)	-0.073* (0.040)
$RESIDUAL\ (-1)$	-0.985*** (0.226)	-0.837*** (0.201)
R-squared	0.741	0.794
Adjusted R-Squared	0.663	0.732
Log likelihood	10.506	9.538
F-statistic	9.513	12.864
Prob (F-statistic)	0.000	0.000
Durbin-Watson Stat	2.141	2.050
Akaike info criterion	-0.260	-0.188
Schwarz criterion	0.076	0.148
Hannan-Quinn criter.	-0.160	-0.088
Jarque- Bera [Probability]	0.493 [0.782]	0.643 [0.725]
Q-stat 1 [Probability]	0.253 [0.615]	0.070 [0.792]
Q-stat 2 [Probability]	0.681 [0.712]	0.283 [0.868]
ARCH Test, F-stat [Probability]	0.533 [0.472]	1.124 [0.300]

****1 percent, **5 percent, *10 percent.*

Both comparative export performance index and the world volume of exports are found once again to be key determinants for value and volume of exports. Interestingly however, the effect of the index of competitiveness is found to be greater on volume of exports than value of exports, while the opposite holds for world volume of exports. A one percent increase in the index of competitiveness leads to a 0.84 percent increase in volume of exports and 0.83 percent increase in value of exports, both being significant at the 1percent level. Enhanced through the use of surrogate measures of incentive for exports like reduction in farm taxation, improvement in quality of exports, and increasing share of the country in global market for the commodity, the index of competitiveness, which reflects the country's competitive advantage in exports of the commodity, is found to be among the major drivers of exports from Chad. A one percent increase in world volume of exports (as a proxy for international trade and demand) leads to 0.85 percent increase in volume of exports and 0.86 percent increase in value of exports from Chad. A potential increase in volume and value of exports from Chad with increasing volume of world trade

indicates that Chad as a cotton exporting nation has a competitive advantage in cotton lint exports, and that should existing inefficiencies in the domestic and global markets be addressed, the country stands benefiting from increasing international trade in the commodity. The insignificant coefficient of the intercept term for model 1 shows that, although volume of exports decreases in the short-run, the decrease is not significant. On the contrary however, value of exports decreases by 0.07 units in the short-run, significant at the 10percent level. This shows that, although the country may have a relatively better shielding capacity on volume of exports for the commodity, the same cannot be said about value of exports, as prices faced by exporters are primarilydetermined exogenously by forces on the international market (notably distortions in the form of subsidies levied by major players). Previous volumes and value of exports have no significant effect on current exports.

Although diverse opinions have been expressed and interesting findings shared in economic, business and trade literature on determinants of export growth, findings from this study generally affirm revelations by Anwar et al (2010), Ball (1966), Ngeno (1996), Nwachuku et al (2010), Ndulu and Lipumba (1990), Takane (2004), Kumar and Rai (2007) and Kumar et al (2008).

V. Conclusion

Following the decline in performance of Chad in cotton production and lint exports, as a result of inefficiencies in both domestic and international policy and market environments, I made use of the Johansen Full Information Maximum Likelihood test to identifying key drivers of exports of cotton lint from the country. In this regard, I defined and estimated two primarily long- and short-run equations using both volume and value of exports as respective dependent variables. Results for therespective normalized and error correction equations show that production, competitiveness in exports, volume of world exports and export price are key determinants of exports, although the effect of the latter in the long-run was significant only for value of exports. In addition, the results reveal that policies drafted and implemented in both the internal and external environments have been more harmful than beneficial to the cotton export industry of Chad. In as much as volume of exports is found to be driven by both internal and external forces, value of exporters is found to be driven more by external forces than internal forces. To revive the Chadian cotton export industry, measures should be put in place to significantly increase production and improve on the country's competitiveness in exports of the commodity (through quality improvement and use of appropriate export enhancing initiatives like reduction in farm taxation. In addition, export enhancing measures used in the 1960s and 1970s could be revisited). Measures should as well be put in place to address existing inefficiencies in the domestic policy and trade environment, as this could suitably position the country to benefit from increases in international trade. Minimization of distortions on the international market for cotton lint could as well play a significant role in reviving the cotton export industry for Chad.

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Appendices

Appendix A : Lag Selection and Co-Integration Test for Model 1.

VAR Lag Order Selection Criteria
Endogenous variables: LNEXPVOL LNEXPPRICE LNPROD LNCEPCHAD LNEXPVOLWORLD
Exogenous variables: C
Date: 05/13/14 Time: 22:05
Sample: 1983 2011
Included observations: 27

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6.932628	NA	1.67e-06	0.883898	1.123868	0.955254
1	61.28769	106.1205*	7.04e-08	-2.317607	-0.877788*	-1.889473*
2	90.60878	34.75092	6.33e-08*	-2.637687*	0.001981	-1.852776

** indicates lag order selected by the criterion*
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Date: 05/13/14 Time: 22:05
Sample: 1983 2011
Included observations: 27
Series: LNEXPVOL LNEXPPRICE LNPROD LNCEPCHAD LNEXPVOLWORLD
Lags interval: 1 to 1

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	1	1

**Critical values based on MacKinnon-Haug-Michelis (1999)*

Appendix B : Lag Selection and Co-Integration Test for Model 2.

VAR Lag Order Selection Criteria
Endogenous variables: LNEXPVAL LNEXPPRICE LNPROD LNCEPCHAD LNEXPVOLWORLD
Exogenous variables: C
Date: 05/13/14 Time: 22:12
Sample: 1983 2011
Included observations: 27

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6.932628	NA	1.67e-06	0.883898	1.123868	0.955254
1	61.28769	106.1205*	7.04e-08	-2.317607	-0.877788*	-1.889473*
2	90.60878	34.75092	6.33e-08*	-2.637687*	0.001981	-1.852776

** indicates lag order selected by the criterion*
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Date: 05/13/14 Time: 22:12
Sample: 1983 2011
Included observations: 27
Series: LNEXPVAL LNEXPPRICE LNPROD LNCEPCHAD LNEXPVOLWORLD
Lags interval: 1 to 1

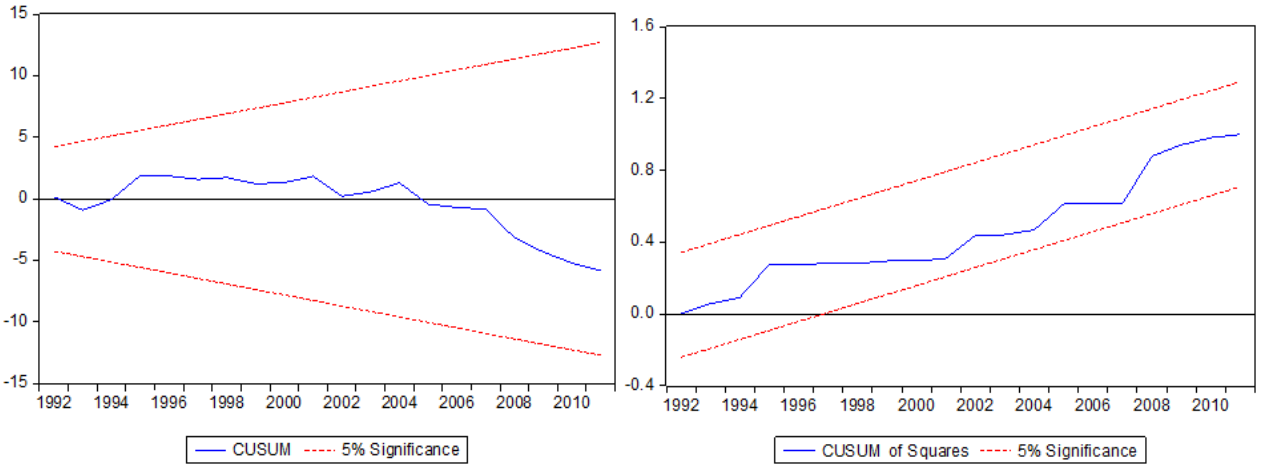
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	1	1

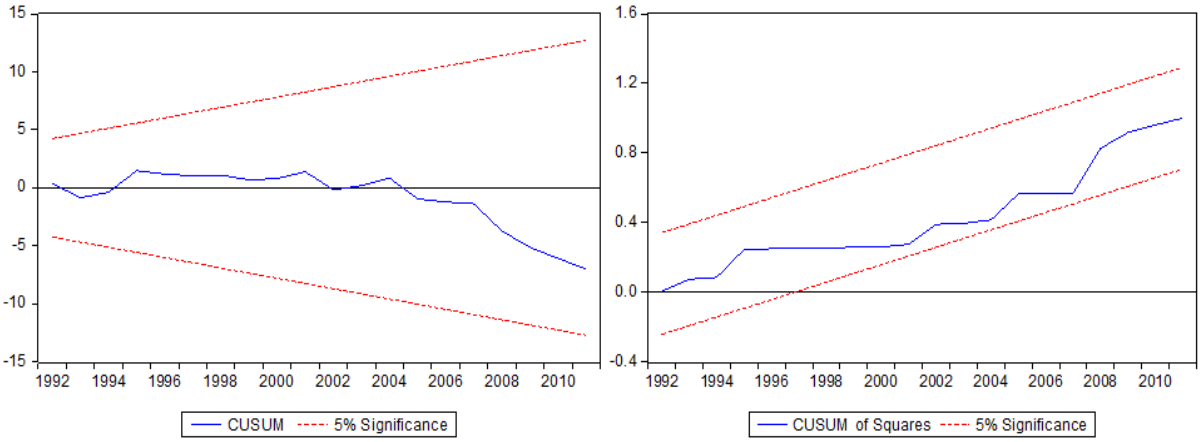
**Critical values based on MacKinnon-Haug-Michelis (1999).*

Appendix C: Stability Test of Coefficients

Model 1



Model 2



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"

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· Present your points in sound order

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- Fundamental goal
- To the point depiction of the research
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- Center on shortening results - bound background information to a verdict or two, if completely necessary
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Approach:

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- Leave out information that is immaterial to a third party.

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The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

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Approach

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- Give details all of your remarks as much as possible, focus on mechanisms.
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- Try to present substitute explanations if sensible alternatives be present.
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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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