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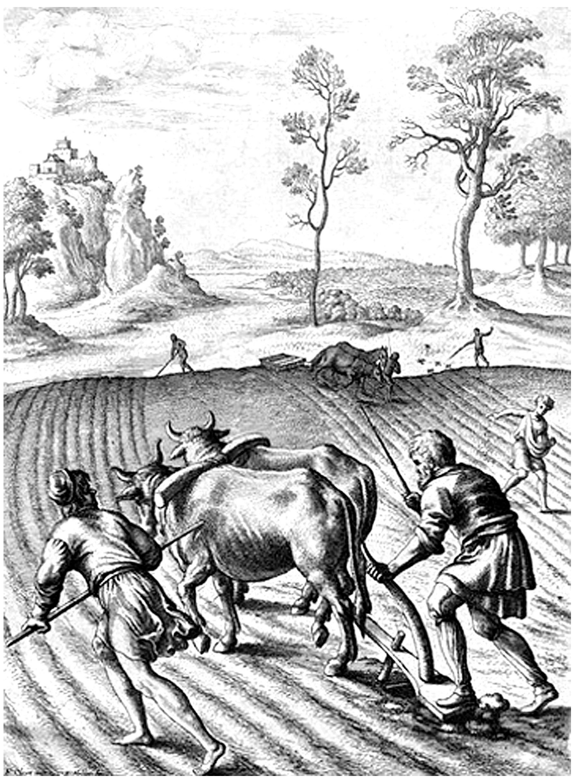

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Soil Water Management and Conservation Practices Towards a New Cropping Pattern in Drought Prone Areas of Bangladesh

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Abstract: Experiment was conducted to increase cropping intensity through soil water management and conservation practices. Transplanted rainfed aman rice is grown in Cropping patterns studied during 2000-01 were rice-legume-legume and rice-fallow-fallow, using early maturing drought tolerant crop varieties and local rice. Tillage treatments were imposed during land preparation. Mulch treatments were also imposed in legume rotations. Newly introduced varieties, BRRIdhan 33 and BINAdhan 4, were earlier by 25 and 15 days, respectively, compared with the local rice Sarna. The early harvest of rice varieties left enough residual moisture due to tillage amendments and mulch applications. The available profile soil moisture left was able to meet up about two-third of the water requirement of chickpea (cv. BINAsola2 and Hyprosola). Pre-sowing irrigation, tillage, mulch practices and little rain contributed to successful production of mungbean cv. BINAmoog 2 after chickpea. A reasonable yield of all the crops was obtained compared with the national average yield. The introduction of chickpea and mungbean in the cropping pattern resulted the cropping intensity from 100 to 300%. The altered cropping pattern (rice-legume-legume) evaluated with the existing one (rice-fallow-fallow) resulted the net return of t 37144.00 to t 55406.00 with BCR value of 1.94-2.40. The achievement of a new cropping pattern was only possible due to introduction of early drought tolerant crop varieties, soil water management and conservation practices.

Key words: Soil water management, conservation, drought, cropping pattern

Introduction

In Bangladesh, production of crops like rice, pulses and oilseeds do not meet the present requirements of the 126 million peoples. Rice being the main food item occupies almost 85% cultivable area and satisfies 90% food requirements despite the production falls short of 2.0-4.0 million tons, each year (BBS, 1999).

Crop production in Bangladesh is mainly dependent on rainfall. Total cultivable land in the country is about 9.4 million ha of which only 35% is under irrigation, the rest being rainfed. Rainfall is mainly confined during June to September (wet season average rainfall:250-500 mm month^{-1}) when most of the indigenous rice cultivars are grown. Out of 9.4 million ha cultivated land, there lies about 0.57 and 1.75 million ha under very severe and severe drought categories, respectively, comprising almost 25% of the cultivable land (Karim ***et al.***, 1990). These 25% cultivable land remains fallow during the dry period, October to May (dry season average rainfall:15-30 mm $month^{-1}$) but natural calamities is quite less. This helps oilseeds, pulse and vegetable crop production, despite later crops need considerable supplemental irrigation. Studies indicate that groundwater level has been declining by 5-10 cm $year^{-1}$ (Hassan, 1994). In such a situation crops with high water demand specially rice, should not be appreciated particularly in the dry months in dry areas to save the environment and maintain ecological balance.

No other crop is effectively grown after rice harvest and the drought prone areas remain almost fallow until arrival of next monsoon. These lands must be utilized for obvious reasons: firstly, it will degrade them further secondly, the country is already food deficient and cannot afford to abandon any land and finally, poor section of the farming community live in these areas with a very low land, holding capacity. Fertilizers used in rice and other crops is also very low and organic matter contents of these soils ranges only from 0.4 to 1.1% (BARC, 1997). Cropping these lands through proper cropping sequence, together with management of soil and moisture will certainly enhance the sustainable balanced crop production of these underutilized drought prone areas of Bangladesh.

The experiment was conducted with the following objectives:

(I) Utilization of developed mutants/varieties in dry areas in a modified cropping pattern with a view to meet up oil and protein requirements and reduce food shortage,

(ii) To monitor soil moisture immediately after harvesting the transplanted rainfed aman rice (July-October) for growing rabi crops (November-February) depending on stored soil moisture in the soil profile,

(iii) To conserve the soil moisture using different types of mulches for relative conservation affects and

(iv) To estimate the reduction in yield due to high drought stress which will serve as another indication of drought tolerance of the varieties.

Materials and Methods

Cropping pattern

The altered different rice-based cropping patterns were selected and evaluated during July 2000 to June 2001 cropping season, with a check that includes current cropping pattern, in the critically drought agriculture at Godagari, Chapai Nwabganj, North-West part of Bangladesh. The selected and control (check) cropping patterns were:

Altered pattern-I

a) Rice cv. BRRIdhan 33-Chickpea cv. BINAsola 2-Mungbean cv. BINAmoog 2

b) Rice cv. BRRIdhan 33-Chickpea cv. Hyprosola-Mungbean cv. BINAmoog 2

Altered pattern-II

a) Rice cv. BINAdhan 4-Chickpea cv. BINAsola 2-Mungbean cv. BINAmoog 2

b) Rice cv. BINAdhan 4-Chickpea cv. Hyprosola-Mungbean cv. BINAmoog 2

Altered pattern-III

a) Rice cv. Sarna-Chickpea cv. BINAsola 2-Mungbean cv. BINAmoog 2
b) Rice cv. Sarna-Chickpea cv. Hyprosola-Mungbean cv. BINAmoog 2

Control or existing cropping pattern

Rice (local cv. Sarna)-Fallow-Fallow

In all the cropping patterns, rice was transplanted on July 21, 2000 with seedlings of the selected rice cultivars when the seedlings were 35 days old with recommended plant spacings of 30 cm in rows of 20 cm apart. Also recommended fertilizer dose of urea, TSP and MP @ 170, 135 and 65 kg ha^{-1}, respectively were applied at the time of final land preparation excepting urea, half of which was applied as top dressing assigned for the cropping patterns were RCBD with 3 replications. Chickpea cultivars assigned for the cropping patterns were sown within 7-10 days (Table 1) after harvests of the respective given patterns. Spacings and fertilizer doses of the respective chickpea and following mungbean crops were followed as recommended. Data on grain and straw yields plot^{-1} (5x4 m^2) were gathered for mungbean and chickpea crops along with detailed yield and yield attributes for the rice crops. It is to be mentioned that mungbean cv. BINAmoog-2 needed one pre-sowing irrigation for successful germination of the seeds. Once the germination is up to the mark and crop was established than profile soil moisture along with rainfall (Table 2) were enough for successful crop growth.

Table 1: Sowing, transplanting and harvest time of different crops

Crops	Varieties	Date of sowing	Date of transplanting	Date of harvest
Rice	BRRIdhan33	14-6-2000	21-7-2000	21-10-2000
	BINAdhan4	14-6-2000	21-7-2000	31-10-2000
	Sarna	14-6-2000	21-7-2000	15-11-2000
Chickpea	Hyprosola	3-11-2000		21-3-2001
		18-11-2000		7-4-2001
	BINAsola2	3-11-2000		21-3-2001
		18-11-2000		7-4-2001
Mungbean	BINAmoog2	25-3-2002		6-7-2001
		11-4-2001		

Table 2: Rainfall amount (mm) during rabi (November-February), kharif I (March-June) and kharif II

	Block I (BRRIdhan33)		Block II (BINAdhan4)		Block III (Sarna)	
Seasons	BINAsola2	Hyprosola	BINAsola2	Hyprosola	BINAsola2	Hyprosola
Rabi	9.0	0.40	9.0	0.4	9.0	0.40
Kharif I	532.60	388.70	532.60	388.70	532.60	388.70
Kharif II	923.0		923.0		923.0	

Tillage and mulch for water conservation

Combination of tillage and mulch treatments was applied in the same rice experimental field. Tillage practices were followed while the land was prepared for rice transplantation. This was done as because most of the rainfall occurs during rice growing period (July-October). That period is suitable to practice any conservation measure to arrest enough moisture from rainfall in deeper layer of soil profile. Mulches mostly from rice straw were used as per treatment and spread @ 3.0 and 4.0 t ha^{-1}, during rabi and kharif I seasons, respectively, to reduce evaporation loss from soil. The treatment were: T_0- no mulch and conventional tillage (farmers practice), T_1- mulch and conventional tillage (country plough), T_2- deep tillage (30 cm depth) without mulch and T_3- deep tillage with mulch.

Soil physical properties and profile soil moisture

The soil physical properties of the experimental soil were also determined following standard and established methods in the laboratory. The soil texture, average bulk density (up to 90 cm depth), basic infiltration rate, electrical conductivity, hydraulic conductivity, field capacity and wilting point of the experimental soil were silty clay loam, 1.70 g cc^{-1}, 0.38 cm ar^{-1}, 0.064 ds m^{-1}, 0.606 cm day^{-1}, 31.88 and 19.88% (by volume), respectively. Profile soil moisture was monitored for each cropping pattern up to 90 cm soil depths after harvests of each crop using Neutron Moisture meter.

Results and Discussion

At the harvest time of rice, soil moisture contents in all the incremental 15 cm depths were higher than field capacity (31.88% by volume). Available soil moisture was calculated based on field capacity and wilting point (19.88% by volume). Available soil moisture in local rice (cv. Sarna) field was relatively low (Table 3) compared with BRRIdhan-33 and BINAdhan-4 owing to 15 days late harvest (Table 1). Late harvest of rice reduced available soil moisture for the next crop through evapo-transpiration process.

Consumptive use of chickpea without moisture limit usually ranges from 15-18 cm (Hassan and Sarkar, 1999) with an average yield of 1000-1200 kg ha^{-1}. From this study (Table 3), available profile soil moisture at harvest of rice was found to be 10.94 cm which is about 5-8 cm less than required

Table 3: Harvest time profile (0-90 cm) and available soil moisture (cm) before inducing mulch treatment

	Block I (BRRIdhan33)		Block II (BINAdhan4)		Block III (Sarna)	
Treatments	Profile	Available	Profile	Available	Profile	Available
T_0	28.68	10.94	28.68	10.94	28.08	10.34
T_1	28.68	10.94	28.68	10.94	27.93	10.19
T_2	28.68	10.94	28.68	10.94	25.73	7.99
T_3	28.68	10.94	28.68	10.94	24.99	7.45

Table 4: Profile and available soil moisture (cm) due to tillage and mulch at harvest of chickpea and mungbean

	Chickpea		Mungbean	
Treatments	Profile	Available	Profile	Available
T_0	6.85	-	28.36	10.62
T_1	19.20	1.86	28.35	10.61
T_2	18.16	0.42	28.68	10.94
T_3	23.41	5.67	28.46	10.72

by the crop. This has indicated that chickpea was under water stress and hence reduced yield (Table 6).

It is evident (Table 4) that profile soil moisture having tillage with or without mulch or vice-versa stored higher soil moisture compared with control at chickpea harvest. Available soil moisture after chickpea harvest was very low and not sufficient enough to grow next crop. This is why pre-sowing irrigation of about 2.5 cm was applied to ensure full germination of mungbean cv. BINAmoog2. Mulches applied as per treatment assisted in reducing the evaporation from soil and ensured germination (Singh and Rao, 1988). There was scanty rainfall (Table 2) during March-June contributing to increase soil moisture in the profile. Available soil moisture at harvest of mungbean (Table 4). It is also evident (Table 4) that without pre-sowing irrigation after harvest of chickpea, mungbean can cot be sown at proper time having required germination. After wards, tillage and mulch practices conserved moisture from rainfall (Table 2) indicated by higher available soil moisture at harvest of mungbean.

Thus soil tillage increased water infiltration, reduced run-off and less evaporation which is evidenced by Nicou and Charreau (1985). Again pre-sowing tillage (during rice transplanting) led to better seedling establishment of chickpea and mungbean, thereby improved crop water use and grain yields which also evidenced by Bationo ***et al.*** (1998).

Evaluation of altered cropping patterns

Results revealed that the rice cv. BRRIdhan33 and BINAdhan4 were earlier by 25 and 15 days, respectively, compared with the local rice cv. Sarna (Table 1). Of the 3 cultivars, BINAdhan4 had produced the highest (Table 6) grain yield (4.08 t ha^{-1}) and in contrast locally adapted cv. Sarna produced the least (3.95 t ha^{-1}) but the difference was non significant (Table 5). All the rice cultivars produced the acceptable levels of moderate yield (3.95 to 4.08 t ha^{-1}) despite one of the cultivars, BRRIdhan33 being the earliest of all (Hamid ***et al.***, 2001).

The existing cropping pattern, rice cv. Sarna-Fallow-Fallow, which is the usual practice of farmers in the drought prone agriculture resulted in the lowest return of t 16,525.00 with BCR value of 1.86. Moreover, the existing cropping pattern resulted the least cropping intensity (100%) of all. Whereas the altered cropping patterns resulted the net return of t 37144.00 to t 55406.00 with BCR values of 1.94-2.40 (Table 5). The introduction of two crops, chickpea and mungbean, in the cropping pattern, were possible due to the practices of the soil water management and conservation measures.

Table 5: The altered and existing cropping pattern structure with crop yields, cost, net return and cropping intensities due to soil water management and conservation practices during 2000-01

Observations /Parameter	Existing cropping pattern T. aman-Fallow-Fallow-	Proposed improved cropping pattern T. aman-Winter pulse-Summer pulse		T. aman-Winter pulse-Summer pulse		T. aman-Winter pulse-Summer pulse	
Land: High Medium varieties used	Sarna- Fallow- Fallow-	BRRIdhan 33 BINAsola 2 BINAmoog 2	BRRIdhan 33 Hyprosola BINAmoog 2	BINAdhan 4 BINAsola 2 BINAmoog 2	BINAdhan 4 Hyprosola 2 BINAmoog 2	Sarna BINAsola 2 BINAmoog 2	Sarna Hyprosola BINAmoog 2
Grain yield	Sarna 3.95 t ha^{-1}	BRRIdhan 33-3.98 t ha^{-1} BINAsola 0.37 t ha^{-1} BINAmoog 2- 0.83 t ha^{-1}	BRRIdhan 33-3.98 t ha^{-1} Hyprosola 0.45 t ha^{-1} BINAmoog 2- 0.93 t ha^{-1}	BRRIdhan 4-4.08 t ha^{-1} BINAsola 2- 0.56 t ha^{-1} BINAmoog 2- 1.0 t ha^{-1}	BRRIdhan 4-4.08 t ha^{-1} Hyprosola- 0.63 t ha^{-1} BINAmoog 2- 0.86 t ha^{-1}	Sarna- 3.95 t ha^{-1} BINAsola 2- 0.53 t ha^{-1} BINAmoog 2- 0.88 t ha^{-1}	Sarna- 3.95 t ha^{-1} Hyprosola 0.88 t ha^{-1} BINAmoog 2- 1.05 t ha^{-1}
Straw yield	4.0 t ha^{-1}	BRRIdhan 33-4.80 t ha^{-1} BINAsola 2- 0.63 t ha^{-1} BINAmoog 2- 2.19 t ha^{-1}	BRRIdhan 33-4.80 t ha^{-1} Hyprosola 2- 0.74 t ha^{-1} BINAmoog 2- 2.14 t ha^{-1}	BINAdhan 4-5.8 t ha^{-1} BINAsola 2- 0.97 t ha^{-1} BINAmoog 2- 2.18 t ha^{-1}	BINAdhan 4-5.8 t ha^{-1} Hyprosola 2- 1.33 t ha^{-1} BINAmoog 2- 2.09 t ha^{-1}	Sarna- 4.1 t ha^{-1} BINAsola 2- 0.88 t ha^{-1} BINAmoog 2- 1.93 t ha^{-1}	Sarna- 4.1 t ha^{-1} Hyprosola 2- 1.05 t ha^{-1} BINAmoog 2- 2.02 t ha^{-1}
Total variable cost ha^{-1}	t 19075/=	t 19075+10200+ 10200=39475/-	t 19075+10200+ 10200=39475/=	t 19075+10200+ 10200=39475/=	t 19075+10200+ 10200=39475/=	t 19075+10200+ 10200=39475/-	t 19075+10200+ 10200=39475/-
Gross return	Grain: t 31600/- Straw: t 4000/- Grand total=t 35600/-	Grain: t31840+8140+29015 =68955/- Straw:=7624/- Grand total=76619/-	Grain: t31840+9900+31885 =73625/- Straw:=7680/- Grand total=81305/-	Grain: t32640+12320+35280 =80240/- Straw:=8945/- Grand total=89185/-	Grain: t32648+13860+29960 =76468/- Straw:=9221/- Grand total=85689/-	Grain: t31600+11660+30625 =73885/- Straw:=6908/- Grand total =80793/-	Grain: t31600+19360+36750/= =87710/- Straw:=7171/- Grand total=94881/-
Net return	t 356000/-	t 37144/-	t 41830/-	t 49710/-	t 46214/-	t 41318/-	t 55406/-
BCR	1.86	1.94	2.06	2.26	2.17	2.05	2.40
Cropping intensity%	100	300	300	300	300	300	300

Prices assumed: From Bangladesh bureauo of statistics; rice t 8.0 kg^{-1}, Chickpea: t 22.0 kg^{-1}, Mungbean: t 35.0 kg^{-1},
Labour charge: t 50.0 day^{-1} labour^{-1}, ploughing: t 120.0 country plough/day and power tiller: t 750.0 ha^{-1}. Deep tillage were made by manual spading where necessary.
1 US$= T 58.0, t stands for taka-local currency

Table 6: Average yield of different crops of the newly developed cropping patterns

Crops	Rabi season (t ha^{-1})	Kharif I (t ha^{-1})	Kharif II (t ha^{-1})
Hyprosola	0.877	-	-
BINAsola-2	0.556	-	-
BINAmoog-2	-	0.911	-
BRRIdhan-33	-	-	3.98
BINAdhan-4	-	-	4.08
Sarna	-	-	3.95

Table 7: Effect of tillage and mulch on the yield of crops

Treatments	Chickpea (t ha^{-1})	Gain (%)	Mungbean (t ha^{-1})	Gain (%)
T_0	0.573	-	0.788	-
T_1	0.873	+63	0.994	+26
T_2	0.622	+9	0.842	+7
T_3	0.787	+37	0.799	+1.5

Even the cultivar cv. Sarna with chickpea and mungbean rotation resulted the highest net return of t 55406.00 with BCR value of 2.4. This might be due to water conservation (mulch and tillage) measures (BINA, 2001) along with the selection of drought tolerant pulse cultivars cv. Hyprosola, BINAsola-2 and BINAmoog-2 during rabi and kharif I season, respectively. Introduction of chickpea and mungbean resulted in the cropping intensity of 300% and was the first kind in drought prone area (Hamid ***et al.***, 2001). Average yield of different crops in new cropping patterns is presented in Table 6.

Table 7 shows the effect of tillage and mulch on the increased yield of crops compared with control treatment. The yield of chickpea cv. Hyprosola and BINAsola-2, was low due to moisture stress because the available moisture (FC-WP) conserved due to tillage and mulch could meet only half of the crop water requirement (Hamid ***et al.***, 2001).

From the results the following conclusions can be drawn:

1: In drought prone area, rice cultivers are well fitted to the environment under rainfed condition with an average yield of 3.7 to 4.0 t ha^{-1} which is about equal to the national average yield.

2: After harvest of rice, chickpea cv. Hyprosola and BINAsola-2, both can be grown with a measure to conserve monsoon rainfall through deep tillage and mulching practice (without any supplemental irrigation).

3: Again after harvest of chickpea, a third crop, mungbean cv. BINAmoog-2 can be grown in the drought prone area with little pre-sowing irrigation for full germination and crop establishment.

4: Soil water management and conservation practices increased the cropping infinity from 100 to 300% with the net return of t 37,144.00 to 55,406.00 and BCR values of 1.94 to 2.40.

5: Farmers in drought prone area need to be motivated through the government extension agency to adopt the altered cropping patterns to earn more net return than existing cropping pattern for higher protein intake and better living.

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